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Vol.32 No.8

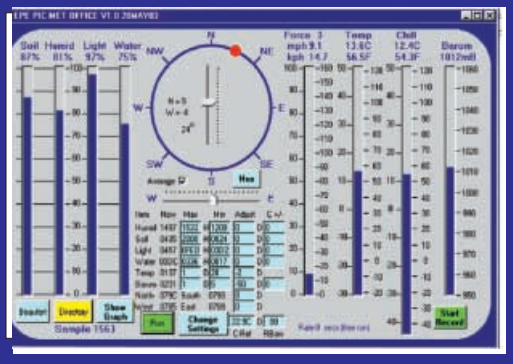
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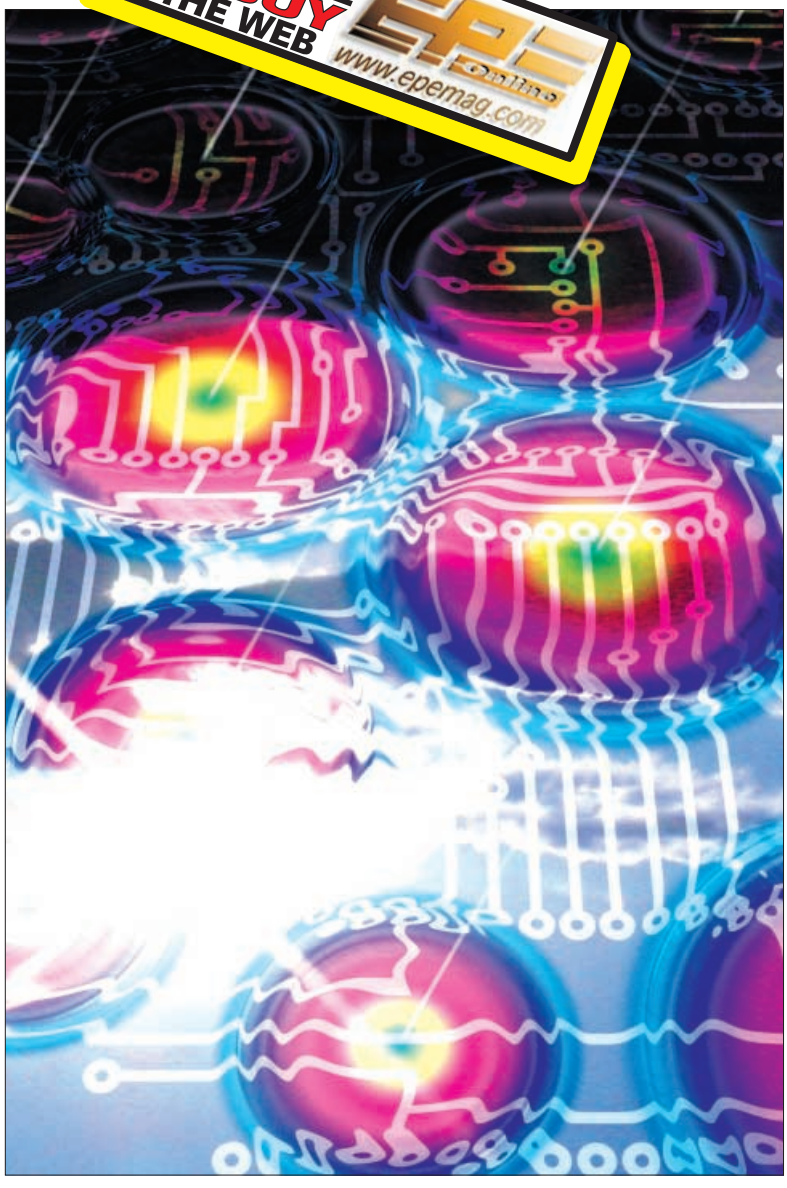
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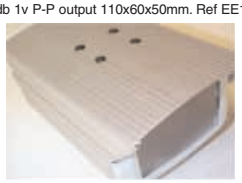
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Built-in Audio .15lux CCD camera 12V d.c. 200mA 480 lines s/n ratio >48db 1v P-P output 110x60x50mm. Ref EE1 £99



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Colour CCTV Camera measures 60x45mm and has a built in light level detector and 12 IR LEDs .2 lux 12 IR LEDs 12V d.c. Bracket Easy connect leads £69. Ref EE15



A high quality external colour CCTV camera with built in Infra-red LEDs measuring 60x60x60mm Easy connect leads colour Waterproof PAL 1/4' CCD 542x588 pixels 420 lines .05 lux 3.6mm F2 78 deg lens 12V d.c. 400mA Built in light level sensor. £99. Ref EE13



A small compact colour CCTV camera measuring just 35x28x30mm (camera body) Camera is supplied complete with mounting bracket, microphone and easy connect leads. Built in audio. Colour 380 line resolution PAL 0.2 us +18db sensitivity. Effective pixels 628x582 Power source 6-12V d.c. Power consumption 200mW £36. Ref EE16



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2.4GHz wireless receiver Fully cased audio and video 2.4GHz wireless receiver 190x140x30mm, metal case, 4 channel, 12V d.c. Adjustable time delay, 4s, 8s, 12s, 16s. £45. Ref EE20



Colour pinhole cctv camera module with audio Compact colour pinhole camera measuring just 20x20x20mm, built-in audio and easy connect leads PAL CMOS sensor 6-9V d.c. Effective Pixels 628x582 Illumination 2 lux Definition >240 Signal/noise ratio >40db Power consumption 200mW £35. Ref £35



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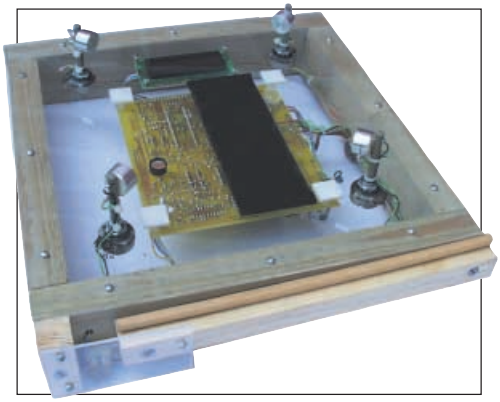
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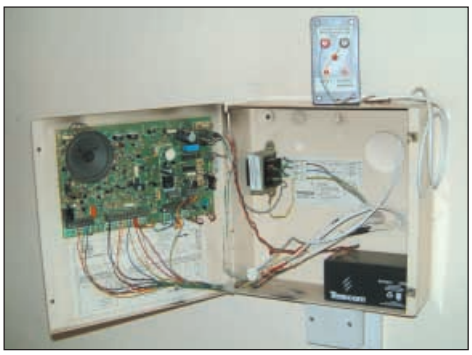
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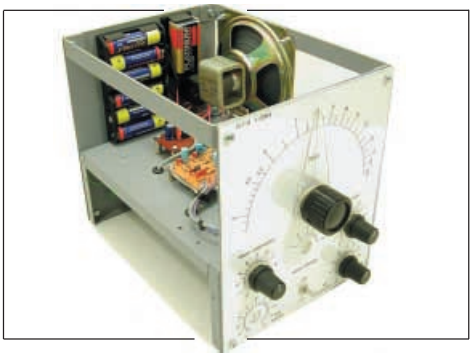
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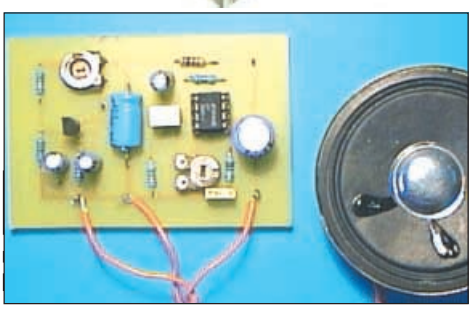
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NEXT MONTH

PIC-A-COLOUR



Readers may remember some years ago there was a popular board game called Mastermind – the one with a photograph of a bearded gentleman and an oriental lady on the box. It was a two-player game and the object was for one person to secretly create a colour code using four coloured pegs, the other person then had to try and guess the colours by putting four coloured pegs into a board full of holes.

The original board game is still available and there have been various commercial electronic versions of the game over the years. PIC-A-Colour is an attempt to emulate the principle of the original game using a PIC microcontroller. In this version the player pits their wits against the PIC, which creates a secret random colour code, the player then has ten attempts to try and guess the code. After each guess the PIC gives the player clues as to how close they got to cracking the code using a seven-segment display.

PIC-A-Colour uses four l.e.d.s, each of which can give four colours, providing 256 possible combinations. The game is addictive and now only requires one player. There is plenty of scope for the constructor to modify the program to increase the difficulty, if required, and some ideas for doing this are given in the article.

TWO MORE TOP TENNERS

PRIORITY REFEREE

In so many competitive games, such as 'Snap' and various quizzes, the winner is the person who is the first to respond. Too often, this turns out to be the person who shouts the loudest! This is clearly unfair and the aim of this circuit is to decide which of two players was really *the first.*

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USING THE PIC'S HIGH COMMAND

On the PIC16Fx series of microcontrollers both program memory and data memory are segmented. Program memory is divided into pages and data memory into banks, and fully accessing them requires the correct use of the PCLATH and STATUS registers.

MPASM and TK3 (from version 1.4 onwards) assemblers provide a feature that greatly simplifies the task of programming PCLATH – the HIGH operator. For those statements that have been assigned a label in a program, the operator HIGH can be used in conjunction with this label to cause the assembler to return the most significant part of the address of the memory location corresponding to the label. This can then be used to automatically set PCLATH without further user intervention.

This technique is recommended wherever possible in any program that could ever conceivably grow to more than 2K program words long, and this article explains how to use it.

PLUS PIC MET OFFICE – PART 2
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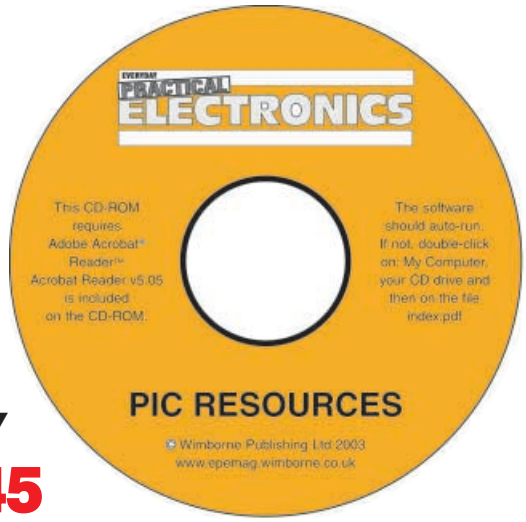
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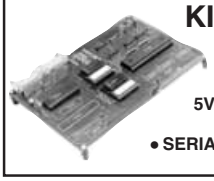


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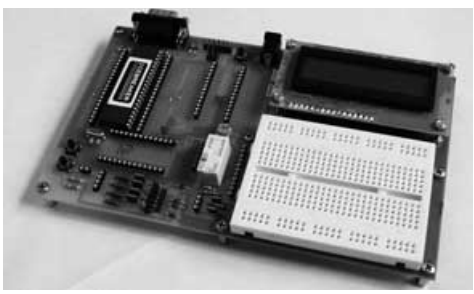
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WEB FEAT

We've been telling you about it for nearly five years now, but it has still to register with some readers. It's the quickest, cheapest method of obtaining *EPE*. At the time of its introduction it was groundbreaking and five years on most other magazines have not yet caught up with us.

Perhaps the regular splash on our front cover, or the numerous mentions in the magazine are not clear enough. Maybe some readers don't understand what we mean. Sure, we can understand why many readers don't want it, but for those that do it's invaluable.

Let me say it again – you can purchase *EPE* from the *EPE Online* Website using a credit card on a secure server and download the latest issue "instantly" to your computer, you can then read it on-screen or print it out to read at your leisure. The cost of this wonderful service that makes *EPE* "instantly" available to readers all around the globe is just $10.99US for twelve issues – that's about £7, or roughly 92 cents or 60 pence per issue – bargain. Yes, it really is that cheap and that available anywhere in the known universe, provided the Klingons have Web access and a credit card!

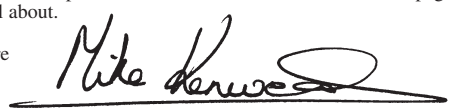
Seriously though, it amazes me to find some readers are still not aware. I received an email from a South African reader recently, it basically said "With the low value of the Rand and high print and shipping costs why don't you do a Web edition of *EPE*?" What a great idea, fortunately Clive (Max) Maxfield and Alvin Brown had the same idea and, as our *EPE Online* Editors, they put it into action in November 1998, try it, it is quite a feat. It certainly was when they did it for us. We believe we were the first printed magazine in the world to have a paid for, instantly downloadable version available from the Web. But, of course, we don't like to shout about it!! *Whisper* – it's at **www.epemag.com**.

STUNNING

Not to be too unkind to some companies there are some pretty awful Websites out there – plus those that never seem to be updated or always seem to fall over. Our own *EPE* Website – the UK one (*not* the *EPE Online* one) at **www.epemag.wimborne.co.uk** has grown in rather a topsy-turvy way since its inception in August 1996; yes, it is seven years old now and anyone who has read *The History of EPE* – available on the Website (the one at **www.epemag.wimborne.co.uk**) – will know that at *EPE* things seem to happen on a seven year cycle.

Because we have continually added to the site over the years, it had become a collection of pages rather than the designed site it started out as when Alan Winstanley first produced it for us all those years ago. It has, of course, served us well but now it has undergone a stunning makeover with various new enhancements, thanks to Alan's hard work. We hope you like it, the basic design comes from Max and Alvin and is in a similar style to the *EPE Online* site (see above if you are not aware of *EPE Online*!), the content, and all the various information pages, search engine, projects listing (going back five years), on-line shop, downloads page, Net Work links, Chat Zone etc., etc., are all down to Alan. Why not take a look? In case you missed them, both the Web addresses are on the front cover, and on this page – in the top right-hand corner, just under our postal address! Alan's *Net Work* column on page 550 will give you a better idea of what it is all about.

With apologies to all those readers who were already well aware of the above.



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We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years old. Letters requiring a personal reply *must* be accompanied by a **stamped self-addressed envelope or a self-addressed envelope and international reply coupons.**

PROJECTS AND CIRCUITS

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.
A number of projects and circuits published in *EPE* employ voltages than can be lethal. **You should not build, test, modify or renovate any item of mains powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.**

COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers (see *Shoptalk*). **We advise readers to check that all parts are still available before commencing any project in a back-dated issue.**

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We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

Constructional Project

ALARM SYSTEM FAULT FINDER



MIKE RICHARDS

A low-cost fault finder that will find a faulty sensor without the alarm system sounding-off incessantly.

WHEN false alarms occur on domestic and on cheaper/older commercial intruder alarm systems it is often difficult to know which sensor has caused the alarm, and even if this is known, many panels do not have a soak test and log facility to test the would-be faulty sensor.

FINDING FAULT

The usual method of fault finding in this situation, after wiring checks, is either:

1) If more than one infra-red, or other sensor is on a single zone it is difficult to know which one is causing the false alarms. The usual method is to sequentially short the intruder contacts out in each sensor, one at a time, and carry on using the system and see when the fault disappears.

2) If a single sensor on a zone is causing false alarms, then the normal method is to short that sensor out in the sensor or at the alarm panel, then carry on using the system and see if the fault has disappeared, or just change the sensor for a new one.

Both methods are not very satisfactory for the following reasons:

(a) The false alarm, complete with bells, sirens, and internal sounders, will keep occurring until the faulty sensor is found and shorted out. This could take many attempts if there are a number of sensors on the faulty zone.

Constant repetitive false alarms, especially at night, are not good for your nerves or for your neighbours' tempers. Eventually any alarm will be ignored, as it will be put down to just another false alarm.

(b) If the sensor is just changed for a new one this could well cure the problem, but it may not, as the false alarms may be caused by vermin within the zone (infra-red etc.) or r.f. interference or mains transients occurring and being picked up by the sensor wiring and introduced into the sensor's electronics.

This simple, easy-to-build, low-cost fault finder project will let you find the faulty sensor without causing the complete alarm system to keep going off.

It can be seen that a logic 0 is also applied to IC1c pin 9, which results in a logic 1 output on pin 10, this being fed back to IC1a input pin 6. The flip-flop is now in the SET condition, and will remain so until it receives a logic 1 at the input of the buffer IC1a (pins 12 and 13).

The normally closed (n.c.) contacts of the alarm sensor "under test" are now connected to the test terminals SK1 and SK2, and Reset button S1 is pressed. From the truth table and circuit diagram it can now be seen that the input to IC1b is at logic 0, and the output of the second gate, IC1c pin 10, is at logic 0. Therefore, if the Interrogate button S2 was pressed transistor TR1 would be reversed biased and so turned off, thus the l.e.d. D1 would not illuminate.

If the sensor's contacts were to open momentarily then the output of IC1c would be latched at a logic 1, even if the sensor's contacts had closed again. Hence, if the Interrogate button is now pressed, transistor TR1 would be forward biased

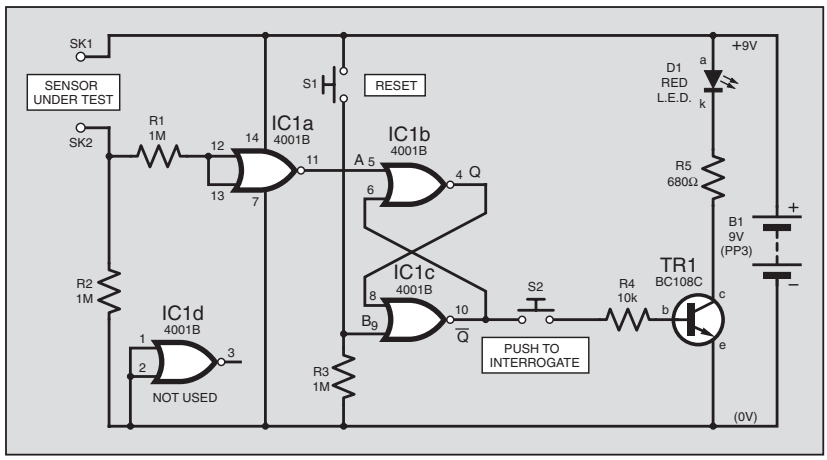


Fig.1. Complete circuit diagram for the Alarm System Fault Finder.

CIRCUIT DESCRIPTION

The full circuit diagram for the Alarm System Fault Finder is shown in Fig.1. The circuit is constructed around a CMOS 4001B quad NOR gate.

The first gate, IC1a, is used as an inverting buffer for the input signal from the detector/sensor on test. The second and third gates (IC1b and IC1c) are connected up to form an SR flip-flop. The fourth gate, IC1d, is not used.

It can be seen from Fig.1 that the inputs to IC1a (pins 12 and 13) on power up are at logic 0 (0V). Thus, the output from IC1a pin 11 is at logic 1 (Vcc or +V).

The output from IC1a pin 11 is applied to pin 5 (Set) of the first gate (IC1b) in the SR flip-flop configuration. From Table 1 it can be seen that any logic 1 applied to a gate input results in a logic 0 output. This logic 0 output from IC1b pin 4 is applied to pin 8 of IC1c, the second "half" of the flip-flop.

Table 1: Truth Table

Inputs		Outputs	
A	B	Q	$\overline{Q}$
0	0	1	1
0	1	0	0
1	0	0	0
1	1	0	0

and l.e.d. D1 would illuminate with current limiting imposed by resistor R5.

Because the quiescent current drain of the circuit is so small no power supply On/Off switch has been incorporated.

CONSTRUCTION

The Alarm System Fault Finder circuit is built on a small single-sided printed circuit board (p.c.b.) and the component layout, together with a full-size copper foil master and interwiring details, are shown in Fig.2. This board is available from the *EPE PCB Service,* code 404.

Commence construction by soldering in position the 14-pin d.i.l. socket for IC1 followed by the five resistors and transistor TR1. Do not insert IC1 into its socket at this stage.

After this the small flexible lead-off wires can be soldered into place. These are to provide the connections to the battery, pushswitches, l.e.d. and test connectors SK1 and SK2.

ASSEMBLY AND WIRING-UP

The next job is to mount the pushswitches, l.e.d. and test connectors on the box lid. After this a battery compartment can be made from an old piece of stripboard or p.c.b. and slotted or glued into place in the box, as shown in the photographs.

The various board lead-off wires can now be soldered onto the front panel components, insulating solder joins with plastic sleeves where necessary (see Fig.2). After visually checking the completed tester for any wiring and connection errors, IC1 can now be plugged into its d.i.l. holder. Take the usual anti-static precautions when handling the i.c.

The completed Fault Finder is now ready for testing.

TESTING

Commence testing by connecting up the 9V battery and then press the Interrogate button (S2). This should cause the "memory" l.e.d. D1 to illuminate.

If all is well, apply a temporary shorting link between the test terminals SK1 and SK2 and press the Reset button (S1). Pressing the Interrogate button should not now cause the l.e.d. to illuminate.

Briefly break the short circuit between the test sockets/terminals. Now pressing the Interrogate button should cause the l.e.d. to illuminate.

If the tester does not operate correctly, immediately disconnect the battery and check all wiring and connections for errors. All p.c.b.-mounted components should also be checked for correct orientation.

If no faults have been found reconnect the battery and check the circuit through, preferably using a logic probe, but failing that use a digital multimeter with a high input impedance (10 megohms or above).

COMPONENTS

Resistors

R1, R2 R3	1M (3 off)	
R4	10k	
R5	680Ω	

All 0·25W 5% carbon film

See SHOP TALK page

Semiconductors

D1	5mm red l.e.d.
TR1	BC108C *npn* transistor
IC1	4001B CMOS quad 2-input NOR gate

Miscellaneous

S1, S2	pushbutton switch, push-to-make (2 off)
SK1, SK2	4mm screw terminals (2 off)

Printed circuit board available from the *EPE PCB Service*, code 404; plastic case, type and size to choice; 14-pin d.i.l. socket; l.e.d. clip; 9V battery (PP3 type) and snap connector; multistrand connecting wire; sleeving; solder etc.

Approx. Cost Guidance Only **£8** ***excl. case & batts.***

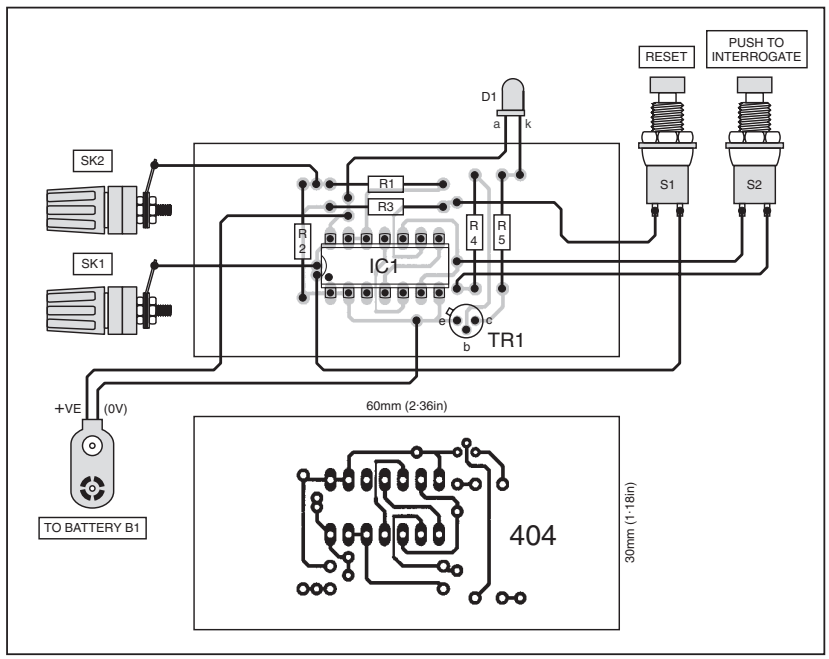
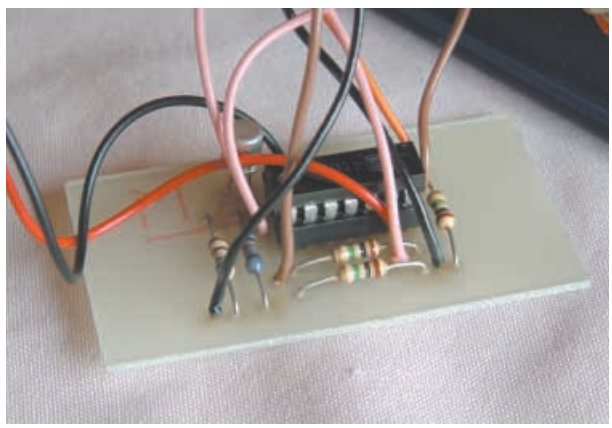


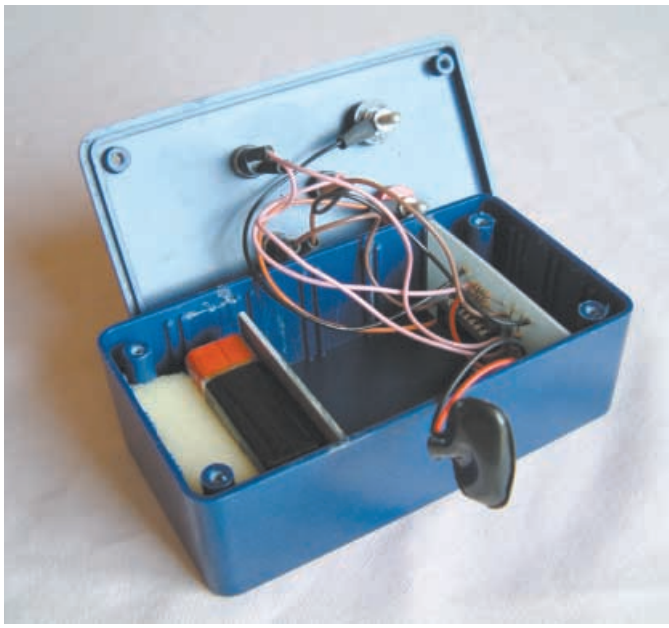
Fig.2. Printed circuit board component layout, off-board interwiring details and full-size copper foil master for the Alarm System Fault Finder. The extra board width is to allow the p.c.b. to slot into the author's plastic box internal "guide rails".





(Above) Completed circuit board removed from its case.

(Left) The finished prototype unit showing general component positioning and lettering on the case lid. Note the "access memory" legend has been amended to "Push To Interrogate" in the final version.



Prototype model showing the p.c.b. and battery compartment divider slotted into the case. The space between boards is to accommodate the lid-mounted components.

POSSIBLE FAULT CONDITIONS

DOOR CONTACT
- Magnet/reed switch out of alignment, and working "just on the edge".
- Old reedswitch whose resistance has increased dramatically.
- Cracked glass reed capsule.

INFRA-RED
- Sunlight falling directly onto the sensor.
- Heat sources within a zone.
- Strong air drafts onto the sensor.
- Animals in a zone.

DUAL-TECH
- Animals in a zone.
- Microwave range not correctly adjusted.

ULTRASONICS
- Animals in a zone.
- Draughts within a zone.
- Heat sources within zone.
- Two sensors "seeing" each other, and are not of the digital crystal controlled type.

USING THE TESTER

Even the most basic alarm panels will usually tell you which Zone has caused the false alarm. Once this is known, how you proceed depends upon how many sensors are connected to the faulty zone.

If one sensor only is fitted, it is necessary to extend the alarm contact wiring temporarily out to the Alarm System Fault Finder input terminals. If the sensor is an infra-red, dual-tech, or ultrasonic device then the tester will have to be located outside the "field of vision" of the detecting device.

After the temporary connections have been made it is also necessary to omit the faulty zone or to short out the zone circuit on the alarm system panel. Then when setting the alarm system also set the alarm system tester unit. This is set by first pressing S1 Reset button and then by pressing S2 Interrogate button. The "memory" l.e.d. D1 should stay extinguished, validating the alarm closed circuit through the would-be faulty sensor.

When returning home or getting up in the morning the intruder alarm system should be turned off first. The alarm "fault finder" unit can now be interrogated by pressing switch S2. If the l.e.d. illuminates this indicates a false alarm occurred during the alarm panel set period, and a false alarm would have normally occurred. If no false alarm occurred it is recommended that the test procedure is used for up to a week to validate the tests.

MULTI-SENSORS

If more than one sensor is fitted across the faulty zone then the zone will have to be broken down in a logical order to identify the faulty sensor. On modern systems it is usual to have one sensor per zone but on cheaper or older systems it is possible that each zone could have two, three, or even four sensors fitted to it.

Depending upon how many sensors are fitted to the faulty zone, two approaches can be taken. The first is to split the sensors into two groups and see which group is faulty, then split these down again and again until the faulty sensor is located.

The other method is to test each sensor, one at a time, perhaps using old knowledge or instinct as to where the fault lays. It can be seen that it will take time to locate the fault and the system's security coverage will be reduced during this time, but at least no false alarms will occur and you can sleep soundly at night, as can your neighbours.

Once the faulty sensor is located it can be replaced or relocated depending upon the fault. If the sensor is not faulty then the fault must be found, this could be due to any one of a number of causes, depending upon the type of sensor fitted.

A general guide to other possible "faults" can be found in the accompanying Possible Fault Conditions panel. Let's hope that "silence is golden" is the password for you and your neighbours! □



The Fault Finder connected to the author's Alarm System panel to monitor a suspect zone sensor.



MOBILE VIDEO BATTLES

Will RadioScape's revolutionary, low cost video broadcasting technique challenge the high investment 3G system? Barry Fox reports.

Two recent demonstrations draw the lines for an imminent battle to create a market and set *de facto* standards for mobile video. DAB and 3G are the opposing contenders.

In the first live demonstration of its kind, British company RadioScape recently joined forces with NTL to show how a DAB digital radio and pocket PC can work like a 3G cellphone to receive video on the move.

"And we have not had to pay billions for a 3G licence", said Radioscape CEO, John Hall.

Video Via Radio

RadioScape had taken over the exhibition area at the top of Tower Bridge in London to show off its new RS 200 DAB/FM/RDS receiver module to the broadcast industry. But shortly before the event RadioScape's engineers succeeded in using the module to squeeze good quality video and sound into a DAB radio channel normally used for mid-fi mono sound.

The Radio Authority waived its usual requirement for ten days advance warning and granted a temporary licence for NTL and RadioScape to broadcast live video by DAB across the bridge.

Flushed with success Radioscape and NTL then joined forces with Microsoft, Texas Instruments and Tandberg to demonstrate the system with news footage from CNN at the National Association of Broadcasters Convention in Las Vegas.

Using Windows Media 9 software, RadioScape converts the pictures and sound into MPEG-4 video, running at just 64Kbps – the rate normally used by radio news stations for mono sound only.

The video is then bundled into Internet Protocol packages and slotted between conventional speech and music radio channels. A DAB module decodes the data for Windows Media Player to play. With a resolution of 176 × 144 pixels, and seven pictures a second, quality on a small screen is surprisingly good. Higher rates give larger, clearer pictures. The inventors claim it even works on a train at 300km/hour.

This is possible because the Digital Audio Broadcast system, developed in Europe as Eureka research project 147, was designed from Day One for mobile use. As a result DAB has already been adopted by 550 radio stations in 30 countries round the world, including Britain, Australia, Canada, India, China, Israel and Taiwan.

The broadcast signal is spread over many narrow frequency channels, so that each channel is carrying only a slow stream of bits. This helps the receiver filter out unwanted interference and reflections. The broadcast bits can convey either low quality mono speech, high quality stereo music, multimedia data, or a flexible mix of all three.

The new mobile video units have a screen and two chip sets, one working like a conventional cellphone and the other working as a DAB radio. Video is "ordered" by a data or text message, at 9·6Kbps, and then received as a DAB signal.

New Video Broadcast Services

RadioScape envisages new services, probably beginning in the Asia Pacific region, where promotional videos arrive free to view, while premium programming, such as winning goals, horse race finishes and breaking news bulletins are scrambled for viewing in return for subscription or fee payment. The video is either continually streamed, like a live news channel, or short clips are repeatedly broadcast for downloading into the handset. A consortium in Taiwan is now trialling a service, browse **www.pc-radio.com.tw/eng/eng_ver.htm**.

In the UK there are seven DAB multiplexes, although usually only three are available in any one area. Each multiplex carries 1·2Mbps, of which UK regulations allow 20% to be used for data. In two or three years time, when new frequencies in the L band are freed for DAB, broadcast capacity will double.

This competes head-on with 3G, the third generation mobile phone service. So far the Three networks in Britain and Italy offer the only commercial 3G service outside Japan. Three is 65% owned by Hutchison of Hong Kong, 20% by Japan's Do-co-mo and 15% by Dutch Telecoms company KPN.

Downloading To Handsets

For £60 (or more) a month the owner of a £400 handset (made by NEC and Motorola) can download MPEG-4 sports, news and comedy clips including Monty Python's Parrot sketch. Each clip lasts about four or five minutes and is downloaded into 32MB of memory in the phone.

The handset has to work either on old 2G or new spread spectrum 3G because the 3G networks are not finished. The leader, Three, can still only claim coverage of 50% of the UK population. When Three handsets move out of range of a 3G base station they will use the Cellnet 02 network for GSM/GPRS reception.

Three says its 3G data speeds range from 120Kbps at the edge of a cell up to 360Kbps, with a theoretical maximum of 384Kbps. Data speed slows with congestion because the wide band fills with signal, which then starts to behave like noise.

Live picture phone video streams at 64Kbps, four to five fps (frames per second). Replay of downloaded video is 7·5fps on the NEC handsets and 15fps on the Motorola. Streaming live video clips will come later. "This is week one of a twenty year project", says 3G's Matt Peacock. Three expects early sales to be conventional early adopters; one thing they will quickly have to get used to is limited battery life, around one hour for video calling and three or four hours for Internet browsing.

Huge Investment

The UK's five rival operators will share 3G sites and towers, but not base stations. So capital investment is huge.

Says Nigel Oakley of RadioScape: "With DAB delivery, startup costs are exceedingly low. There is no licence to buy and no infrastructure to build".

Says Phil Kendall, wireless specialist with industry analysts Strategy Analytics: "There's no escaping the beauty of the idea. As an alternative to blowing around £8 billion on a 3G licence and network, and then being one of five, the logic is compelling. The struggle is not technical, it's to compete with marketing clout of the majors, like Vodafone".

Vodafone paid the UK government a record price of £5·964 billion, just for a licence to run a 3G service. Vodafone's network will be ready by the end of this year. The company's spokeswoman on 3G admitted she was unaware of the DAB system, but assures: "We are committed to 3G. It's in full flow. There's no stopping it now".

TRILOBITE ROBOTIC VACUUM



ELECTROLUX have announced the introduction of the Trilobite, a vacuum cleaner that takes care of the cleaning all by itself. The Trilobite is the first automatic vacuum cleaner in the world. It should be on sale in Sweden by the time you read this and will be exported to other European countries early next year.

The Trilobite has been under development for several years in Sweden. "This has been quite an exiting journey," says Hans Straberg, CEO of the Electrolux Group. "We presented a prototype in 1997 to see if the market was interested. The response was overwhelming."

The vacuum cleaner is 13cm high and has a diameter of 35cm, which means that it can even clean under beds and tables. It "sees" with the aid of ultrasound – just like a bat. The system allows it to quickly detect a dog's water bowl, legs of chairs, walls and other obstacles. Once any of these are detected the Trilobite calculates a new path. Near stairways and other places where there are no natural obstacles, you place special magnetic strips to prevent the Trilobite from passing through.

Electrolux say that the Trilobite can easily be left alone to take care of cleaning carpets while its owners are out enjoying themselves. The expected cost of the Trilobite is around £999.

For more information browse:
http://trilobite.electrolux.se and **http://news.bbc.co.uk/1/hi/technology**.

CHIP REPAIR

IN this age of throw-away obsolescence, it comes as a surprise to learn that a Scottish microelectronics company is offering repair facilities for integrated circuits.

The Microelectronics Imaging and Analysis Centre (MIAC) has been given funding of more than £200,000 by Scottish Enterprise Edinburgh and Lothian to upgrade its facilities. Part of that upgrading programme will include the introduction of a new technique that will allow the repair of copper based i.c.s which are now increasingly replacing those that use aluminium.

The new technology will mean the Edinburgh based centre will be the only commercially operated facility in Europe capable of carrying out the repairs on copper interconnected devices.

SDRAM ACHIEVES 4-GIGABYTE

SAMSUNG say they have taken memory capacity to the next level by creating the industry's first 4-gigabyte Double Data Rate (DDR) Dual In-line Memory Module (DIMM).

For more information browse **www.samsung.com**.

WEBBED PRINCIPLES

EPT Software tell us that in order to enable more students and hobbyists to enjoy their Electronics, Mechanics and Computing Principles 8.1 software, they have changed their marketing strategy to one of only supplying via their web site as downloadable installations at substantially reduced prices.

With more than a thousand interactive topics, version V8.1 is a huge interactive resource of technical information, including topics ranging from reading resistor colour codes to PIC programming, mathematics and computer science subjects. EPT say that in fact there are few electronics topics not covered and that many engineers install the software on their laptops in preference to carrying heavy textbooks for reference material.

Clive Humphris of EPT says, "This change of strategy has opened up lots of new opportunities for us and it brings many advantages to our customers, the most significant is being able to make future upgrades available free of charge by simply downloading the latest version."

EPT Software is an authorised Curriculum Online software content provider and retailer.

For more information browse **www.eptsoft.com**.

PIC Training

MATRIX Multimedia, whose PIC-related products include such renowned CD ROMs as *Assembly for PICmicro* (formerly *PICtutor), C for PICmicro* and *Flowlog*, have announced three one-day courses for those who want to learn or teach PIC microcontroller programming.

Each month Matrix is running one-day courses in assembly code programming, C programming and flow chart programming at the company's new training facility in Halifax, West Yorkshire. The aim of each course is to introduce the basics of PIC programming and to give delegates the confidence and all the resources they need to carry on learning at home.

Matrix say that the course is particularly suitable for teachers who have an interest in introducing PIC programming to their school or college.

A full specification of the training days can be browsed at:
www.matrixmultimedia.co.uk.

Science Experiments

PICO Technology ask if you are interested in conducting science experiments? If you are, their new DD103 Oxygen-in-Air sensor will probably appeal to you. It is for use with Pico's popular low cost Dr Daq data logger. The galvanic cell sensor just plugs into one of Dr Daq's external sockets and can measure a full 0% to 100% oxygen level range.

Dr Daq itself simply connects to your laptop/desktop PC, taking power from the PC, so no batteries are required. It runs with the supplied PicoLog data acquisition software and converts the PC into a powerful, yet easy to use, scientific instrument.

This new oxygen sensor broadens the range of biology, physics and chemistry experiments (such as oxygen produced by plants during photosynthesis) that can be conducted in primary and secondary schools. It retails for £99 plus VAT. The Dr Daq data logger and software retails for £59 plus VAT.

For more information contact Pico Technology Ltd., Dept EPE, The Mill House, Cambridge Street, St Neots, Cambs PE19 1QB. Tel: 01480 396395. Fax: 01480 396296. Email: peter@picotech.com. Web: **www.drdaq.com**.

Distance Learning

OakCAD Training has taken over the whole operation of the National College of Technology Distance Learning Programme, a college which has for many years supported electronic enthusiasts, with courses such as Electronic Circuits, Digital Circuits, and Testing and Fault Diagnosis, all of which offer to the successful student a half or full unit for a BTEC Certificate.

OakCAD Training has over 10 years of engineering and CAD training experience and offers a range of customised engineering courses. Some of these courses are currently being developed in a distance learning format for delivery on CD.

This development will enhance the service offered to anyone interested in learning more about electronics and engineering.

These and other courses can now be booked through OakCAD on their web site: **www.oakcad.co.uk/nct.aspx**, or telephone 08456 345 445.

INTERFACE

Robert Penfold



OPTICAL SENSING HEART-RATE INTERFACE FOR YOUR PC

USING the serial port handshake inputs as general-purpose inputs and for counting pulses at low frequencies has been covered in recent *Interface* articles. In this month's *Interface* article a practical counting application will be described

The obvious pulse counting application is just that – counting the number of heartbeats per minute. This requires some form of interface to provide the electrical pulses for the computer to count, and there are two common methods of producing the necessary signals. One is to use electrodes on the subject's body to detect the electrical signals generated as each heartbeat occurs, and the other is an optical system.

In many ways the direct electrical method is the more interesting approach, but it does have one or two drawbacks. One of these is that it requires a very large amount of amplification to bring the weak electrical signals in the human body up to a level that will drive the inputs of a PC at suitable levels.

This tends to give problems with pick-up of the electrical noise generated by the PC and the monitor, and with mains "hum" and other electrical noise in the environment. Another problem is that the interface must be electrically isolated from the PC in order to conform to safety regulations.

Shining Through

The second method is simpler and avoids the two main drawbacks of the direct electrical approach. The basic scheme of things is to shine a continuous light through the subject's finger and onto a photocell. Although there is no obvious reason for this generating a signal in sympathy with the subject's heartbeat, it does actually do so.

In order to generate a signal the photocell must be connected in a potential divider circuit across the supply lines of the interface. The variations in blood flow produce small changes in the amount of light passing through the subject's finger. It is possible to use other parts of the body such as an earlobe, but monitoring via the end of a finger is generally the easiest method.

The signal generated by this method is quite small and a large amount of amplification is required in order to drive the serial inputs of a PC. Mains "hum" and other electrical noise is not a major problem with this method because the user is electrically isolated from the interface.

With the direct electrode method the subject effectively acts as an aerial, picking up any electrical noise in the vicinity. This makes it difficult to obtain a "clean" signal, and balancing techniques have to be used to cancel out the electrical noise in the environment. This is unnecessary with the optical method, which also avoids problems with electrical isolation, since the isolation is an innate part of the system.

Heart-Rate Circuit

For the sake of simplicity the optical method has been adopted for the Opto-Sensing Heart-Rate PC Interface, and the full circuit diagram appears in Fig.1. It is based on the *Heart Rate Monitor* published in the *Ingenuity Unlimited* feature of *EPE* May 2003 circuit, by Tony Lee. R2 is the photocell and R1 is its load resistor.

A cadmium sulphide photocell is a good choice for this application where good sensitivity is an advantage and only very low frequency signals are involved.

An ORP12 light-dependent resistor (l.d.r.) was used for R2, but virtually any cadmium sulphide photo-resistor should work in this circuit. With some alternatives it might be necessary to alter the value of R1 in order to obtain good results.

High-Gain

The output of the photocell circuit is coupled by capacitor C2 to the input of a two-stage high-gain amplifier based on IC1 and IC2. IC1 operates as a non-inverting amplifier having a voltage gain of approximately 30 times. Capacitor C3 rolls-off the high frequency response of

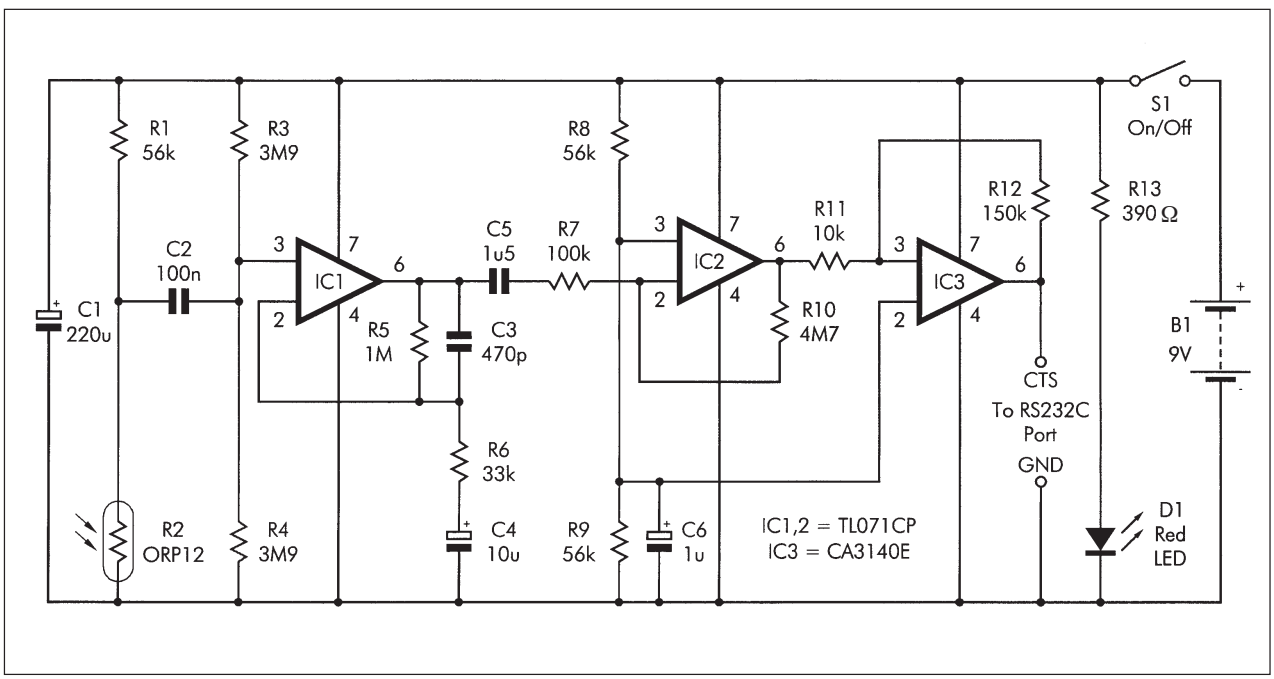


Fig.1. Complete circuit diagram for the Opto-Sensing Heart-Rate Interface. R2 can be practically any photo-resistor, such as the popular ORP12 light-dependent resistor (l.d.r.). Note that the light source (D1) must be an ultrabright or superbright light-emitting diode (l.e.d.).

the circuit, which helps to avoid problems with instability.

Capacitor C5 couples the output of IC1 to the input of a simple inverting amplifier based on IC2. Feedback resistors R7 and R10 set the voltage gain of this stage at about 47 times, giving an overall voltage gain of approximately 1400. This should be sufficient, but if necessary the gain can be boosted by increasing the value of resistors R5 and (or) R10.

It is important that the signal fed to the computer is reasonably "clean", since any glitches will substantially boost the pulse count and give poor accuracy. The output signal also has to be at voltages that will drive an RS232C input reliably. The output of IC3 is therefore fed to a simple trigger circuit that has a moderate amount of hysteresis provided by resistor R12.

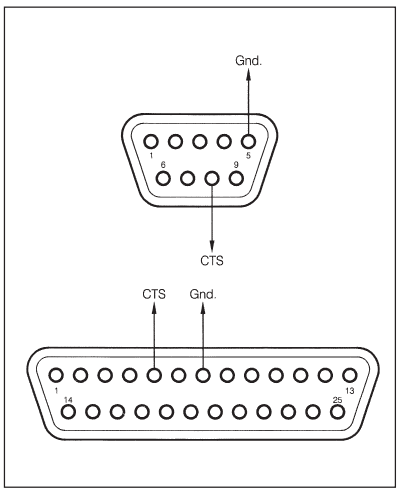


Fig.2. Connection details for 9-pin and 25-pin serial ports.

Although the output signal is not at full RS232C signal voltages, the circuit should drive any normal RS232C port reliably, provided a connecting cable of no longer than two or three metres is used. The output of IC3 could be fed to a proper RS232C line driver if preferred, but there will normally be no advantage in doing so.

Seeing the Light

In order to work properly it is essential for this opto-sensing method of detection to have a reasonably strong light source above the subject's finger, with the photocell on the opposite side of the finger. Also, light from mains powered lighting must be kept away from the photocell as it will tend to produce ripple on the output of IC2 which could produce multiple pulses as the output of the trigger stage changes state.

In days of yore a small light bulb was used as the light source in this type of equipment, but these days an l.e.d. is a better choice. An l.e.d. provides a similar light level but at much lower current consumption. D1 is the l.e.d. used as the light source and resistor R13 is the current limiter resistor. The current fed to D1 is just less than 20mA, which should be enough to provide sufficient light from any ultra-bright or super-bright l.e.d. A "bog standard" l.e.d. is unlikely to give sufficient light output in this application.

Resting Comfortably

It is important that things are arranged in such a way that the user can rest his or her hand comfortably. Any movement of the user's finger is likely to generate spurious signals. For the same reason it is important that the photocell and l.e.d. are fixed firmly in place. Any wobble in either is likely to cause spurious signals.

In all other respects construction of the interface is perfectly straightforward, but bear in mind that the CA3140E used for IC3 requires the usual anti-static handling precautions. Only two connections are made to the RS232C port, and connection details for nine and 25-pin ports are shown in Fig.2. The current consumption of the interface is about 25mA, so it is best to use a fairly high capacity battery such as six AA size cells in a holder.

Software

Regarding the Visual Basic software, the form must be equipped with a label having a suitably large font size to act as the digital readout. Another label component having an appropriate caption such as "Heartbeats Per Minute" is placed above the readout label. The form must also be equipped with MSCOMM and a timer having its Interval value set at 15000 milliseconds (15 seconds).

The following is the code for the heart rate program:

```
Dim Counter As Variant

Private Sub Form_Load()
MSComm1.PortOpen = True
Label1.Caption = 0
End Sub

Private Sub MSComm1_OnComm()
If (MSComm1.CommEvent = comEvCTS) Then
Counter = Counter + 1
End If
End Sub

Private Sub Timer1_Timer()
Label1.Caption = Counter * 2
Counter = 0
End Sub
```

The first line declares a global variable called Counter, which is used to store the pulse count. The subroutine for the form simply switches on the serial port and sets the readout at an initial value of zero.

A simple If...End If routine waits for transitions on the CTS handshake line and increments Counter by one each time a transition is detected. Every 15 seconds the subroutine for the timer sets the caption of the readout label at double the current value in Counter, and then resets Counter to zero so that a fresh count can commence.

Since the count only lasts 15 seconds rather than a minute, the value displayed must be four times the number of input pulses that are counted. However, the count is augmented each time there is a transition (rather than a pulse) on the CTS line. The count therefore increases by two for every complete input pulse, and the value in counter only has to be doubled in order to give a reading in beats per minute. The resolution of the system is therefore two beats per minute.

It can be increased to one beat per minute by using an Interval value of 30000 for the timer and writing the value in Counter straight to the readout label. Of course, this has the drawback of updating the readout only twice instead of four times per minute.

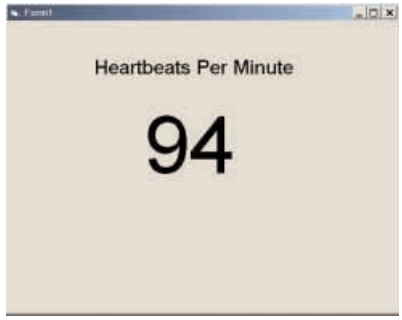


Fig.3. Screen shot showing the heart-rate monitor in operation.

In Use

The program in operation is shown in the screen shot of Fig.3. The system works well considering the simplicity of the interface, but it is advisable not to have the interface too close to the PC or the monitor. Keeping the interface reasonably well separated from the computer system helps to minimise any electrical noise from the computer being picked up by the interface's sensitive amplifier.

It is essential to keep light from mains powered lighting from reaching the photocell, and for the subject's finger to remain still relative to the photocell. Displayed pulse rates into the hundreds will occur if noise and spurious pulses are allowed into the system.

Note that the circuit necessarily has an extended low frequency response, and that this results in it taking several seconds after switch-on for the voltages in the circuit to settle down to their normal operating levels. It will also take a few seconds for things to settle down after the subject's finger is placed over the photocell, due to the large initial pulse this produces.

Refinements

There are one or two refinements that can be made to the Visual Basic program. An on-screen indicator could be used to show the transitions on the CTS line. This would be useful when initially setting up the system, and would also make it obvious if there were any problems with glitches.

The pulse counting method used here should guarantee reasonably accurate results, but the display does not update very often. More frequent updates can be obtained by measuring the time taken for (say) four input pulses, and then using some mathematics to convert this time into the equivalent beats per minute. It can be difficult to get consistently accurate results using this method, but it would be an interesting approach to try.



Constructional Project

EPE PIC MET OFFICE



JOHN BECKER

Part One

Forget the seaweed and proverbs, let technology cater for your insatiable interest in the weather!

THE *EPE Met Office* of December '95 and January '96 was the last Weather Centre to be published in these pages. A lot of water has passed under many bridges since then, in more ways one!

One flood has been in the way that readers have taken to PIC microcontrollers during that period. As long as three years ago we recognised that the time was ripe to publish another Weather Centre, this time using a PIC16F877 and its ready capability of monitoring many types of sensor simultaneously.

It was also obvious that this device could easily be used in conjunction with serial memory chips, to perform long-term data recording for subsequent download to a PC-compatible computer for analysis. The technique for such recording had already been proved in the author's *PIC 8-Channel Data Logger* (Aug/Sep '99).

SOLID STATE

There was a problem, though. It lay not so much in the basic monitoring and logging, as with the author! He had rashly said that the next weather centre he did should be entirely solid state – no moving parts whatsoever.

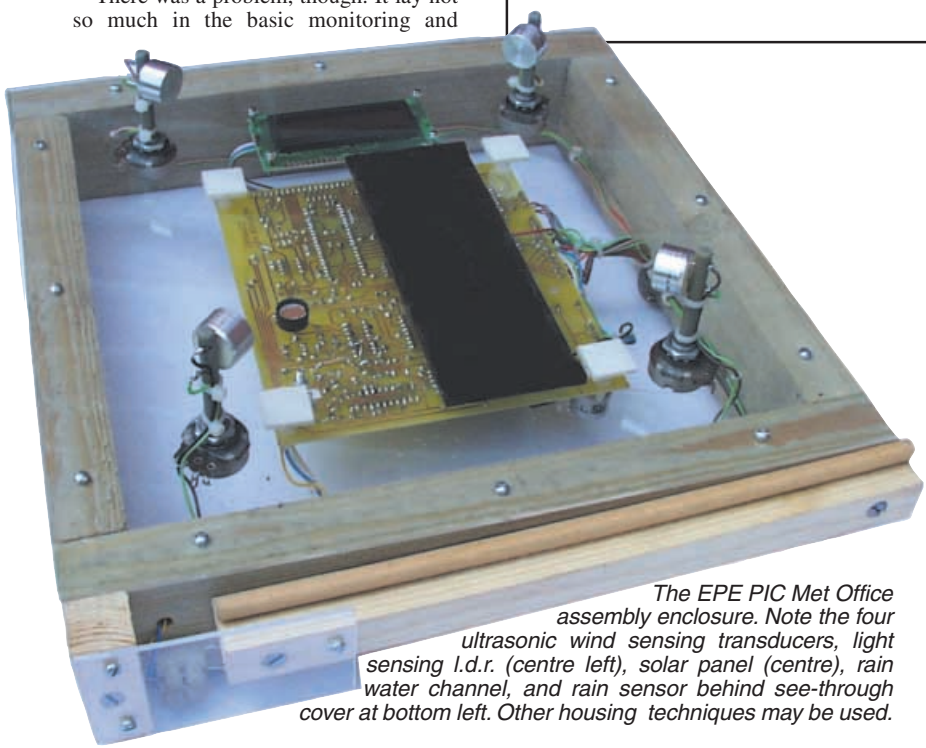
As most of you will know, traditionally a weather centre has always had two moving parts, an anemometer for measuring wind speed, and a vane that indicates the direction from which it blows. For readers (and the author), for whom electronics is the chosen technological path to be passionate about, mechanics is the *weakest link – goodbye to all that*, seemed to be the prevailing thought.

So, the reasoning was that electronics by now should be capable of sensing wind speed and direction without resorting to rotational mechanics. There were many ideas of how it *might* be done, but no practical experiments had been performed in Tech Ed's garden. But, after much shilly-shallying and putting off the hard work, he's done it now. As to how, be patient a moment, all will be revealed. First, take a look at the Specifications for what *this* PIC Met Office can do overall!

SPECIFICATIONS . . .

The PIC Met Office monitors a range of sensors and processes data for the following conditions:

- Barometric pressure, in millibars
- Temperature, in °C and °F, including sub-zero
- Atmospheric relative humidity, as an RH percentage
- Soil moisture, bone-dry to saturated, as a percentage
- Light intensity, as a relative percentage, full sun to total darkness
- Rain fall, immediate (is it raining *now*?)
- Rain fall, cumulative (by how much has the water barrel filled and over what period?)
- Wind speed, in kph, mph and Beaufort, immediate and averaged
- Wind direction, immediate and averaged, 0° to 360°
- Wind chill factor
- Rainbow alert!
- Recording of all data to non-volatile serial memory (up to 256 kilobytes)
- Selectable data sampling rates, from 1 second to 1 hour intervals
- Serial output (9600 baud) of realtime and recorded data to PC-compatible computer, running under Windows 95/98/ME
- Bargraph and waveform displays on PC
- Data formatted by PC for reading as text file compatible with Excel spreadsheet/graphing software and text editors
- Immediate display of monitored sensor values via alphanumeric liquid crystal display



The EPE PIC Met Office assembly enclosure. Note the four ultrasonic wind sensing transducers, light sensing l.d.r. (centre left), solar panel (centre), rain water channel, and rain sensor behind see-through cover at bottom left. Other housing techniques may be used.

Note that you do not *need* to use a PC if you are content to just observe the l.c.d. readout and ignore the data logging option. In this case the serial memory devices and PC interface components can be omitted.

SATELLITE TECHNOLOGY

As will be described presently, a PIC16F877 microcontroller is the brain of the system. In effect, it sits in a commanding position surrounded by several satellites of sensors, variously providing data in response to active control or passive sampling. See block diagram Fig.1.

In turn each of the sensors comes under the attention of the PIC, which acquires that sensor's data and formats it for display on an alphanumeric liquid crystal display (l.c.d.). The full cycle takes about one second to complete.

Secondly, the PIC has been provided with the option to store that data to up to eight on-board serial EEPROM (electrically erasable programmable read-only memory) chips if required. Simultaneously, the PIC constantly outputs data in a serial format for immediate reception via a cable link to a PC if connected.

When requested by the user, the PIC can output all recorded serial EEPROM data to the PC as a block.

The functioning of the control unit will be described presently (Fig.12), but first the sensors are examined in turn.

LIGHT SENSING

One of the simplest sensors in this design is that for sensing light level. Its circuit diagram is shown in Fig.2.

The sensor is an ORP12 (or similar) light dependent resistor (l.d.r.), notated as LDR1. Its resistance is very high (several megohms) in total darkness, falling to just a few tens of ohms in bright sunlit conditions.

Somewhat unusually, it is fed with a digital pulse train provided by the PIC via pin RE2. The l.d.r. is in series with a ballast resistor, R24, and with a capacitor, C13. The rate at which C13 charges between two specific voltage levels in response to the pulses is timed. From this the PIC determines the relative resistance value of the l.d.r. and relates it to the upper and lower extremes of the l.d.r.'s resistance range, from which a percentage value is obtained.

The junction of LDR1 and C13 is coupled through a multiplexer (IC3, see Fig.3) to the PIC's Port A Schmitt trigger input, at pin RA4.

In simple terms, the pulse train from PIC pin RE2 is initially taken low, causing C13 to discharge through LDR1 and R24. As soon as the logic level at RA4 is recognised as being at logic 0, the pulse is taken high to start C13 charging up again. When the PIC recognises that a logic 1 level has been reached, as detected by the upper Schmitt trigger threshold of RA4, it again reverses the pulse logic and starts a timer.

Capacitor C13 starts discharging again. When RA4's logic 0 Schmitt threshold is reached, the timer is stopped and its value read. This is compared with values previously established during the PIC Met Office's initial setting up, and a percentage value relative to maximum light level is calculated.

SOIL MOISTURE SENSING

A similar technique is used to assess the relative moisture content of garden (or pot plant) soil. As discussed in the author's *Earth Resistivity Logger* (Apr/May '03), the resistance that soil presents to a current

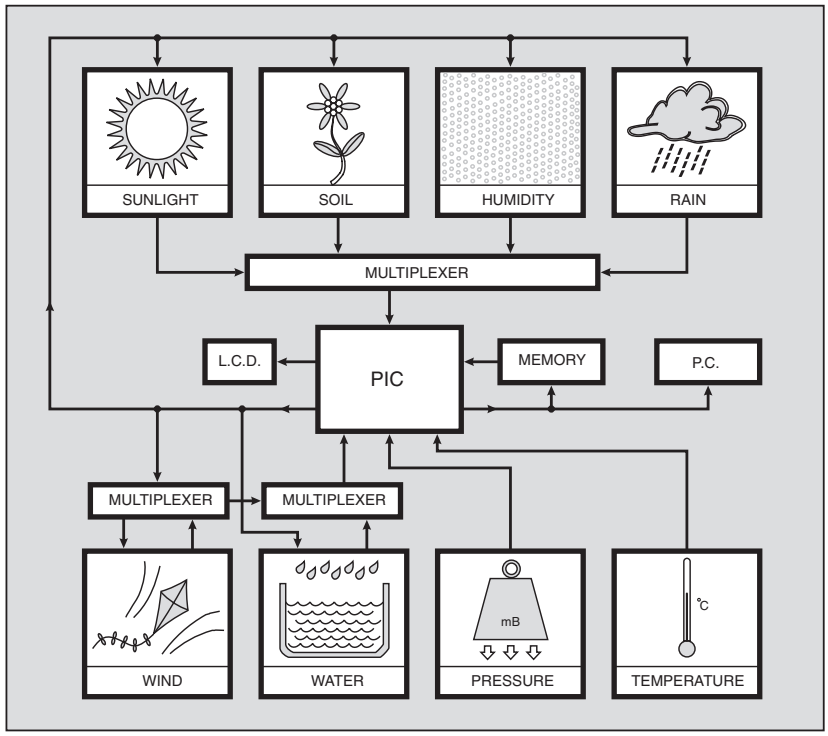


Fig.1. Block diagram of the EPE PIC Met Office.

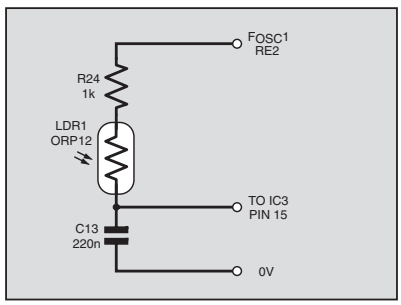


Fig.2. Light sensing circuit.

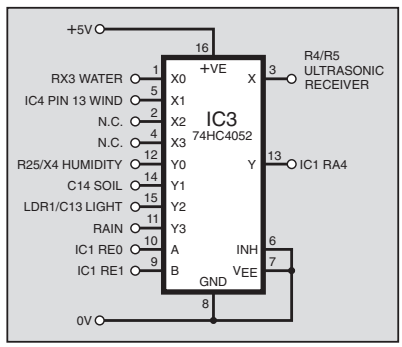
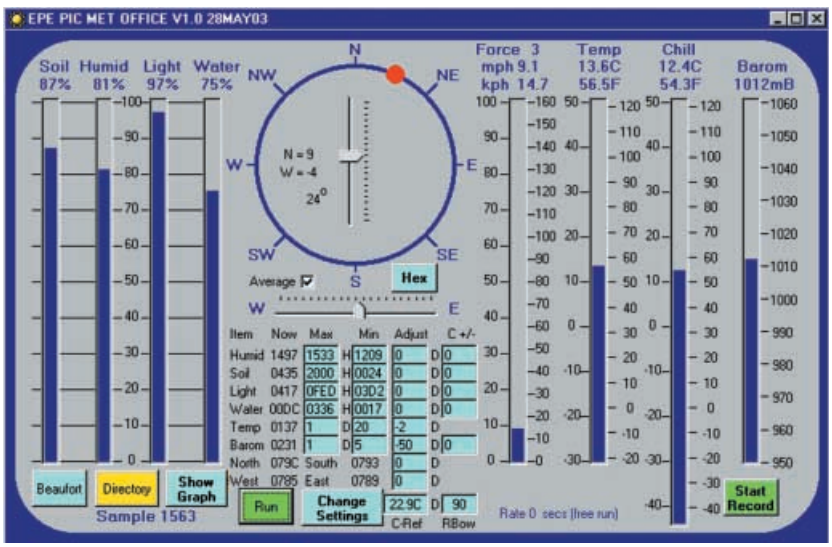


Fig.3. Multiplex circuit through which most of the sensor signals are routed to the PIC microcontroller.



Example of the PIC Met Office's main display on a PC-compatible computer screen.

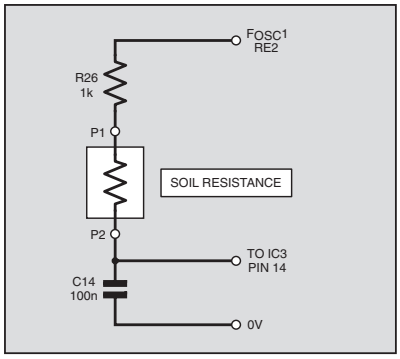


Fig.4. Soil moisture sensing circuit.

fed through it varies depending on its moisture content and general make-up. A very high resistance is present with dry soil, and a very low resistance for wet soil. In this context, the chemical nature of the soil, which may also provide conductivity, has a small effect by comparison to water content.

The circuit diagram for the soil moisture sensor is shown in Fig.4. The circuit is essentially the same as that in Fig.2, except that the l.d.r. resistance is replaced by the soil's resistance. Once again a capacitor, C14, is charged and discharged by the pulse train from RE2, acting via a ballast resistor, R26.

Note that the alternating signal also helps to prevent polarising effects being generated in the soil, and corrosion of the probes, as would happen if a direct current (d.c.) were fed into it. The situation is discussed in the *Earth Resistivity Logger* (and its software contains a text file describing experiments that can be carried out to show the effects).

Physically, two external probes are connected to the soil sensor circuit, one to resistor R26 at point P1, the other to capacitor C14 at point P2.

The voltage level at C14 is fed via multiplexer IC3 (Fig.3) to PIC pin RA4. As with light level sensing, the timings between the logic thresholds are used to determine the soil's relative resistance in relation to preset wet/dry extremes as established during setting-up.

HUMIDITY SENSING

A similar timing technique is used for sensing the relative humidity (RH) of air. The circuit diagram is given in Fig.5.

Here the sensor itself (X4) is the capacitor, in series with two resistances, R25 and preset VR3, the latter setting a basic range for the CR (capacitance-resistance) relationship.

The sensor has a capacitance whose value changes with relative humidity. The range is typically 110pF in dry air (RH 0%), to 145pF in saturated air (RH 100%). It is the same sensor type discussed in *Teach-In 2002* Part 3 (Jan '02).

Again the timing factor at the "capacitor" is sensed by PIC pin RA4, via multiplexer IC3. The extremes of the sensing range are established during setting-up, using two "real" capacitors of known value (to avoid a long wait between total air dryness and saturation conditions – which might never occur!).

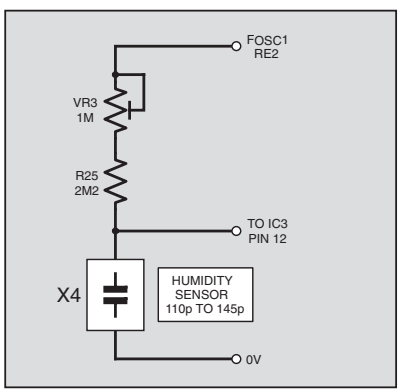


Fig.5. Humidity sensing circuit.

RAIN SENSOR

The presence of rain is assessed by the simple technique of detecting whether two closely adjacent "probes" are conducting, see Fig.6. They are placed such that rain falling on them accumulates into droplets, growing large enough to periodically cause electrical conduction to take place between them through the water before the drip runs down, breaking contact.

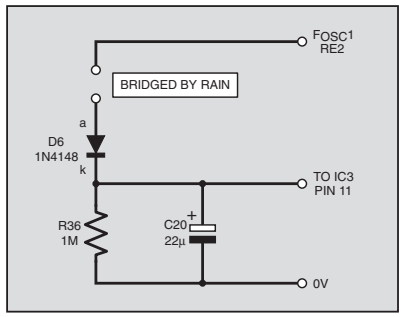


Fig.6. Rain sensing circuit.

One probe is fed with a pulse chain from PIC pin RE2. As with soil moisture detection, the use of an alternating signal reduces probe contamination caused by polarizing currents.

When inter-probe conduction takes place, pulses from the receiving probe cause capacitor C20 to charge via diode D6. The resulting voltage is coupled via multiplexer IC3 to PIC pin RA4. The PIC simply detects whether or not this pin is receiving a voltage above or below its logic threshold levels. If the voltage is at a logic 1 level, then it's raining, or the rain drip has not yet dispersed from the probes.

In the absence of a rain drip, C20 is discharged via resistor R36.

TEMPERATURE SENSING

The temperature sensing circuit diagram is shown in Fig.7. It is essentially the same circuit as used in the author's *PICronos L.E.D. Wall Clock* (May/June '03).

It is based on the type LM35CZ temperature sensor, IC7. The voltage output of this device varies by 0·01V per degree Celsius. It has been configured with two 1N4148 silicon diodes in its ground path in accordance with its manufacturer's datasheet. This allows the device to respond to sub-zero temperatures. Resistor R27 provides a bias path to 0V to suit this role.

The voltage difference between IC7's output and negative pins is processed by the differential amplifier formed by op.amps IC8a to IC8c. Note that the op.amp is a quad rail-to-rail device. A "standard" quad op.amp, such as an LM324 for instance, is unsuitable in this application. A rail-to-rail device *must* be used.

The circuit configuration around the three op.amps provides a gain of ×10, providing an output voltage change at IC8c pin 7 of 0·1V/°C. Some resistors are 1% types in order to provide this gain precision (which is actually ×9·99 – but near enough to ×10 to be acceptable). A span adjustment option is provided by the software but its use should not be needed.

Differential amplifier circuits were discussed in depth in *Teach-In 2002* Part 5 (Mar '02).

The output from this circuit is fed directly to one of the PIC's pins (RA3) configured as an analogue-to-digital-converter (ADC) input. The ADC provides a 10-bit conversion range (1024 values) for voltage inputs of between 0V and the supply rail voltage (5V).

PRESSURE SENSOR

Barometric pressure sensing is performed by the circuit in Fig.8. The pressure sensor itself is notated as X5. It is a compensated termperature bridge device of which two arms, 1 and 3, are used in a current-control configuration between output pin 14 of op.amp IC6a, and the inverting input at pin 13. The resistor values (for R13 to R16) are those recommended in the device's datasheet. Note that R15 and R16 are 1% types, used in series to set a value of 806Ω (the datasheet's value).

The sensor's twin outputs, at pins 2 and 4 are in antiphase, and are fed to the two inputs of another differential amplifier, formed around op.amps IC6b to IC6d. A "standard" op.amp type LM324 is used for IC6, rail-to-rail ability not being needed for this circuit.

Some resistors in the amplifier are also

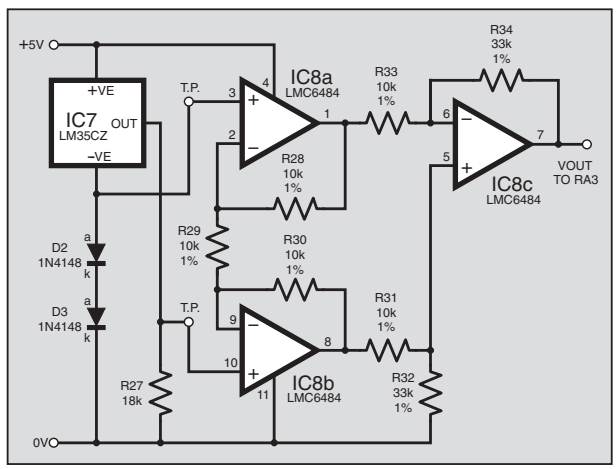


Fig.7 Temperature sensing circuit.

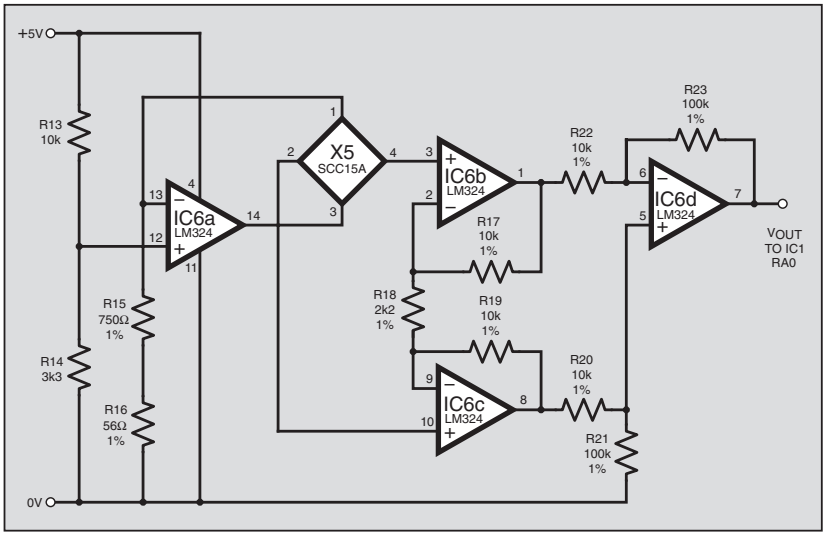


Fig.8. Barometric pressure sensing circuit.

specified as 1%. However, the use of 1% tolerance here is not as crucial as with the temperature circuit. The software provides span alignment to suit individual sensors. The circuit gain is about ×30.

The output voltage at IC6 pin 7 is fed to another ADC pin at the PIC, RA0.

WIND SENSING

In the author's *PIC Wind Speed Meter* (Jan '03), a technique for sensing wind speed by timing the rate at which ultrasonic pulses passed between two ultrasonic transducers was first described in *EPE*. Even though the ultrasonic transducers are sold as matched transmitter/receiver pairs they can in some circumstances be used interchangeably.

In this PIC Met Office, the technique is employed again, but this time four ultrasonic transducers are used, arranged at the four corners of a square. Ultrasonic pulses are exchanged between the transducer pairs at opposite corners. In the physical construction, these corners are positioned in line with standard compass points, N, S, W, E.

The principle allows not only wind speed to be assessed, but also its direction (with the aid of a bit of maths in the PIC's software!). It works as follows:

Transducer N transmits a couple of ultrasonic pulses towards transducer S. The time it takes for the pulses to cross the short distance (about 25·5cm) is measured. Transducer S now transmits towards N, and again a timing is taken.

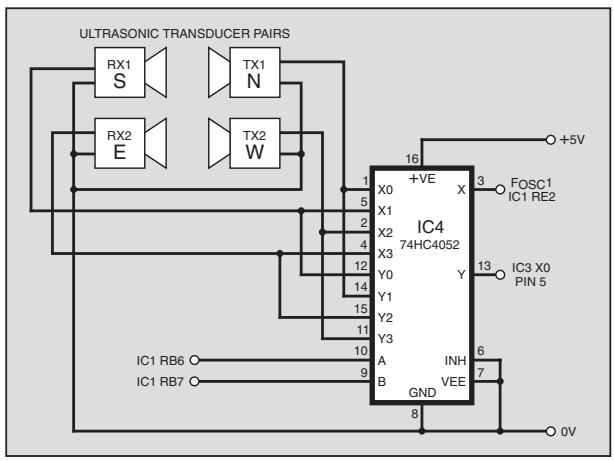


Fig.9. Wind sensing transducer multiplexing circuit.

Next transducers W and E exchange pulses and timings are taken. Standard geometry is used to manipulate the four results to provide the dominant angle at which the air is flowing between the transducers' known angular positions. From knowledge of the wind angle, relative wind speed can be established.

Both values are, of course, based on the rate at which sound travels through air (332m/s at 0°C). If the air is moving (there's wind) the rate varies accordingly, faster if the sound is travelling with the wind, slower if it is travelling against it.

Because the transducers alternate between being transmitter and receiver, the effects of temperature change, humidity and barometric pressure can be ignored in this simple application.

Wind by its nature is blustery, constantly changing speed and direction as it swirls passed. Only an average typical rate and direction can ever be established in any low-cost unit (and greater precision is probably very difficult to achieve even in an "expensive" design).

The basic ultrasonic signal routing circuit diagram is shown in Fig.9. PIC pin RE2 is fed to multiplexer IC4 at analogue pin X. The binary code on IC4 pins A and B determines the output path that the signal takes, from X0, X1, X2 or X3.

These four pins are each connected to the signal pin of one transducer. The same transducer pins are also connected to IC4 pins Y0, Y1, Y2 and Y3. According to the code on pins A and B, the selected path is output at IC4 pin Y.

The routing is arranged so that, for example, when transducer N is transmitting the ultrasonic signal from X0, transducer S is receiving the pulses and passing them via Y0 to Y. Conversely, when S is transmitting from X1, N is receiving and outputting via Y1 to Y. Internally, the unselected paths within IC4 are held at high impedance and have no effect on the transducers or the output signal at Y.

PULSE AMPLIFIER

From IC4 pin Y, the output signal is fed via multiplexer IC3 (Fig.3) to the amplification circuit in Fig.10. Here it is amplified by the a.c. coupled circuit around op.amps IC5a and IC5b. The basic gain is ×100 for IC5a, and between approximately ×0·5 and ×100 for IC5b, as set by preset VR2. This allows plenty of scope for the signal amplitude at the output of IC5b, pin 1, to be adjusted to provide clean pulses to the following stage around transistor TR1.

From IC5b, the output signal is a.c. coupled to the base of TR1 via capacitor C11. The base is biassed normally-low by resistor R11, so that the collector of TR1 is normally high. Pulses from IC5b that exceed the transistor's turn-on threshold, of about 0·6V, drive the transistor into saturation. The resulting line level (0V to 5V) pulses are fed to the PIC at its RB4 input.

The inclusion of resistor R4 was found necessary to minimise any noise signal from the receiving transducers when their transmitting counterparts are not being pulsed.

Capacitor C12 minimises the transitory effect of received pulses that fall between the transistor's fully on and fully off conditions.

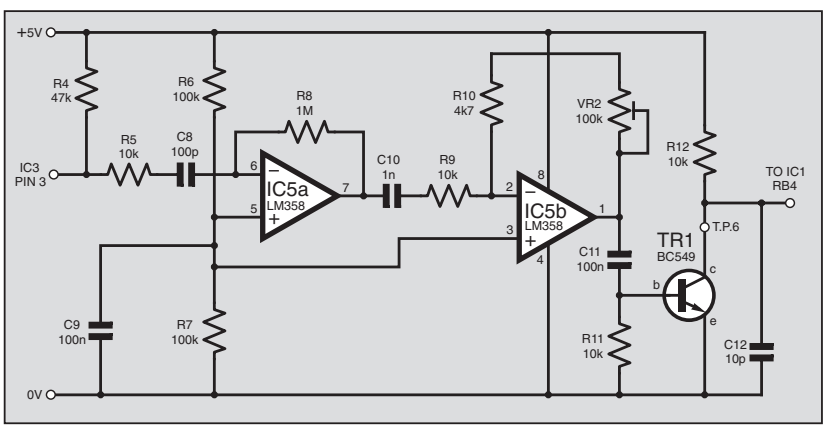


Fig.10. Ultrasonic pulse reception amplifier circuit.

WATER LEVEL SENSING

As with the author's previous weather centres, provision has been made to keep track of the water level in a garden water barrel used for collecting rain. Ultrasonic techniques are also used here. The basic circuit is shown in Fig.11.

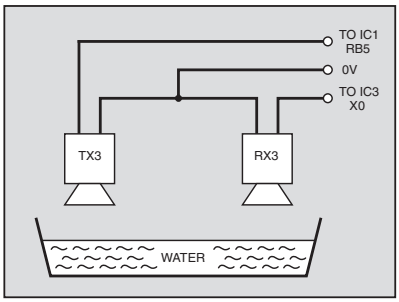


Fig.11. Water level sensing circuit.

A "tapemeasure" principle is used to assess the distance of the water surface. Both transducers, TX3 and RX3, are positioned side-by-side above the water barrel and facing down into it. Transducer TX3 is pulsed by PIC pin RB5, transmitting a signal into the barrel. Transducer RX3 receives the echo pulse and feeds it via multiplexer IC3 to the amplifier in Fig.10.

Having transmitted the ultrasonic pulse, the PIC waits a brief "masking" period to allow RX3 to cease any sympathetic "ringing" while TX3 is transmitting. A timer is then started. It is stopped immediately the PIC receives the amplified and shaped echo pulse from TR1.

During setting-up, timing ranges for a water barrel in both empty and full conditions are established. In "active service", the received echo pulse timings are compared with the empty/full values and a fullness percentage value calculated.

RAINBOW ALERT

The Rainbow Alert is just a bit of a fun gimmick, prompted by some light-hearted banter on the *EPE Chat Zone*! It is based on the logic that **IF it is raining AND the sun is shining, THEN it is worthwhile having a look for a rainbow**!

Of course all sorts of other criteria determine whether or not a rainbow *will* be seen, such as your viewing angle in relation to the direction of the sun's rays and their refraction by the rain drops.

The Alert is only available via the PC. If it detects that rain is present at the same time as light intensity is above a preset level, then seven concentric circles of "rainbow" colours are displayed on screen. They vanish when the trigger condition has passed.

CONTROLLER CIRCUIT

Since designing the previous Weather Centres, technology has moved on in the form of PIC microcontrollers coming into widespread use. How did we ever do without them? The simple answer is "with difficulty and ingenuity"! Considerably more complex logic techniques had to be used with the previous designs.

In this design, all the sensor control and monitoring functions are simply performed by feeding a few wires into a few PIC pins, and the software takes care of the rest. (We'll gloss-over the fact that software can take considerably longer to write than the joining of numerous logic chips into a coherent system! This design has around 3600 PIC software commands.)

The circuit diagram in Fig.12 shows the PIC microcontroller, IC1, and its connections. It is operated at 10MHz, as set by crystal X1. The connections are not only those to and from the sensors, but also those to the other functions that give this design flexibility.

Having discussed the sensors, those other functions are now examined. The role of switches S1 to S5 will be discussed when setting-up is described.

SERIAL MEMORY

Data from all the sensors can be stored to a bank of non-volatile serial memory chips for subsequent download to a PC. The size of the memory bank is left to personal choice, but can range from one serial memory chip, to eight. (You may also

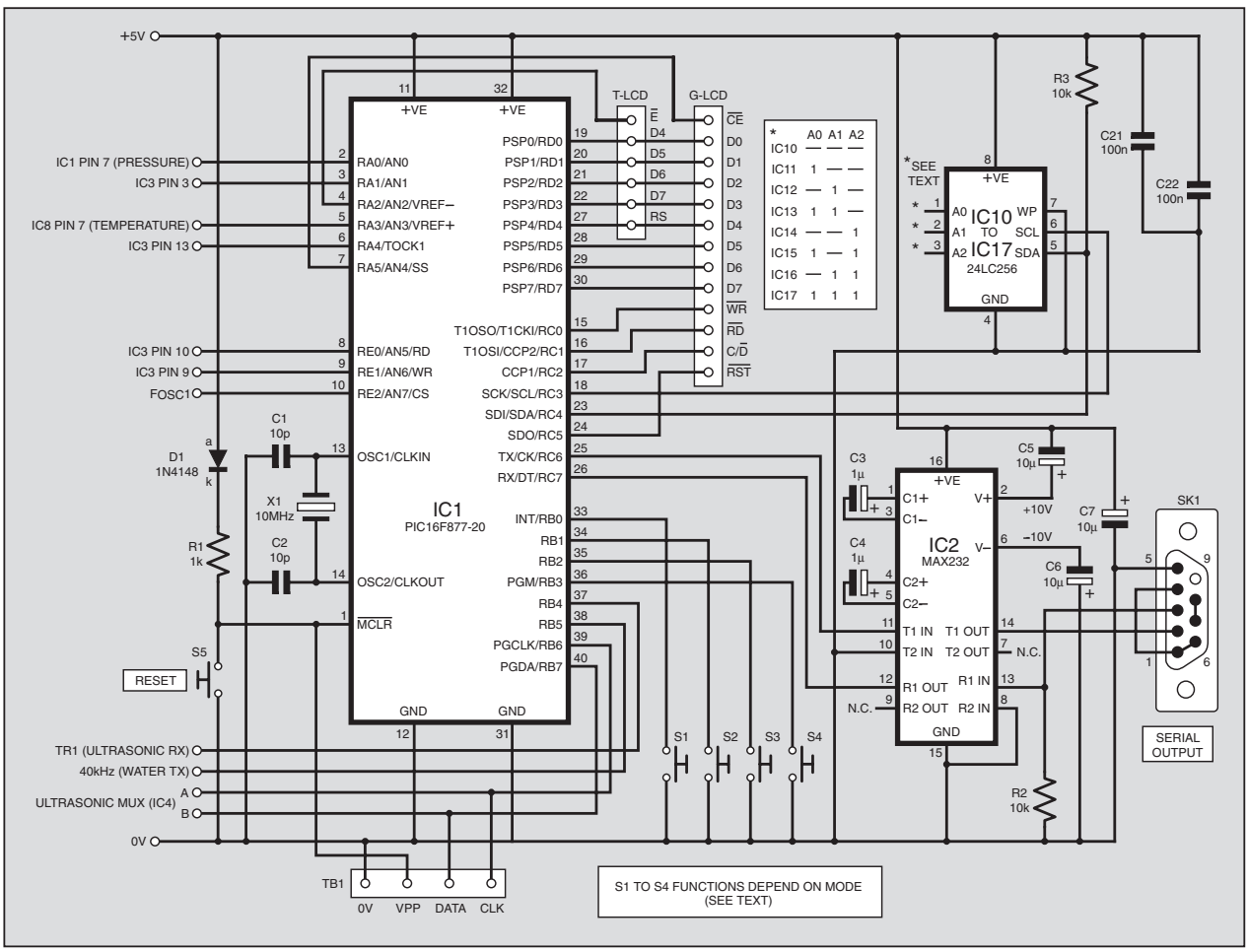


Fig.12. Circuit diagram for the main controller, data storage and output functions.

choose to omit them entirely if you prefer.) They are represented as a single device notated as IC10 to IC17 in the controller circuit diagram, Fig.12.

The serial memory chip type is the same as previously used in the author's data logging designs, the Microchip 24LC256. This has 256 kilobits of memory, used as 32768 8-bit bytes (32K), but using two bytes for storing the data from a single sensor. The use of the 24LC256 was briefly discussed in the author's *PIC Tutorial V2*, Part 3 (May '03).

The memory chips are coupled in parallel and jointly accessed via a single pair of data input and output connections, via PIC pins RC3 and RC4. The chip to be accessed is selected by an identity code transmitted by the PIC. Until another ID code is transmitted, only the selected chip will respond to data being sent or demanded for retrieval.

The eight memory chips have their identity hardwired on the printed circuit board by setting a binary code on their A0 to A2 pins. Internally, the pins are biassed normally-low, so it is only necessary to connect the selected pin to the +5V line. The inset block diagram to the left of the IC10 to IC17 symbol shows the logic 1 connections for all eight chip addresses.

Data is transferred between the PIC and the memories via their SDA (serial data) pin, in conjunction with a clock signal applied to pin SCL (serial clock). A single resistor, R3, biasses the SDA pins normally high as they are "open-collector".

Any data stored to the memory chips is retained even after the power has been switched off.

The PIC Met Office can be used without any memory devices if on-board logging facilities are not wanted. Simply omit any memory chips not needed, but resistor R3 must be used whatever the quantity, providing a known bias level to the PIC should it try to read back data from a non-existent chip.

When memory is installed, the PIC constantly writes data to consecutive addresses at a rate preset by the user, as discussed in Part 2. Having reached the end of the available memory, it restarts from the beginning again. When data is downloaded to the PC, the formatting ensures that the samples are saved to disk in the correct time sequence.

PC INTERCONNECTION

Connection between the PIC and a PC is made serially via the RS-232 chip, IC2. Whilst it is often possible to directly connect a PIC to the serial port of a PC, this interface technique is best reserved for situations when only a few bytes of data are to be exchanged at irregular intervals.

Transferring large blocks of data is more reliable if an RS-232 interface chip is used. This ensures that the interface voltage levels are optimised for serial data transfer. Handshaking between the PIC and PC when in block transfer mode also helps to ensure data transfer accuracy.

The interface device used is the commonly available MAX232. In conjunction with capacitors C3, C4 and C6, this device generates logic signals swinging between typically ±10V on its output pins T1out and T2out.

Data is transmitted from IC2 pin T1out to the PC via socket SK1 pin 2. Handshake signals are received by IC2 pin R1in via SK1 pin 3. Resistor R2 biasses pin R1in to 0V to ensure stability when the PC link cable is disconnected.

L.C.D. READOUT

In addition to the PC providing readout facilities, the hardware also provides an alphanumeric liquid crystal display (l.c.d.) readout. PIC Port D is used to control the l.c.d., whose connections are shown in Fig.13. The Port D connections to the l.c.d. are notated in Fig.12 within the outline marked T-LCD (text l.c.d.).

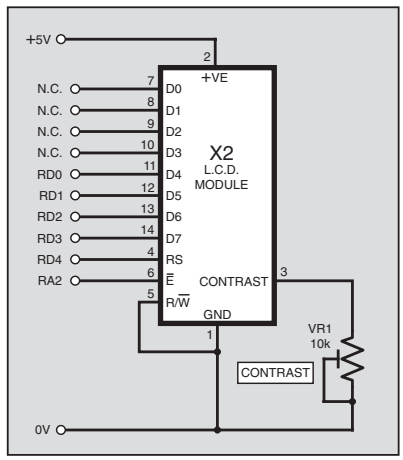


Fig.13. Circuit diagram for the text l.c.d. module X2.

It will be noticed that there is an adjacent outline and connections marked as G-LCD. These connections may be used by the author in some future update to also provide a display using a graphics l.c.d., such as that in his *How to Use Graphics L.C.D.s with PICs* (Feb '01).

If such an update takes place, the display connections shown in Fig.14 will be used, the display being notated as X3. The negative supply inverter required for the graphics l.c.d. is shown as IC18. Its output voltage determines the l.c.d.'s screen contrast, which can be adjusted by preset VR4.

Do note though, that the author offers no assurances that he will ever add this facility, but the connections are already there should he encounter a rainy day and nothing else to do! Of course, you can always write your own program for it!

POWER SUPPLY

The circuit diagram for the power supply is shown in Fig.15. Basically the unit is intended to be powered by a battery source (B1) providing between 9V and 12V. Via diode D5, this supply is regulated down to 5V by IC9.

The option to also use a solar cell/panel is provided (X6), although the unit can be powered by only a battery if preferred. The solar panel generates a voltage related to the amount of sunlight (or other strong light source) falling on its surface. At peak light intensity, the solar panel listed can generate up to

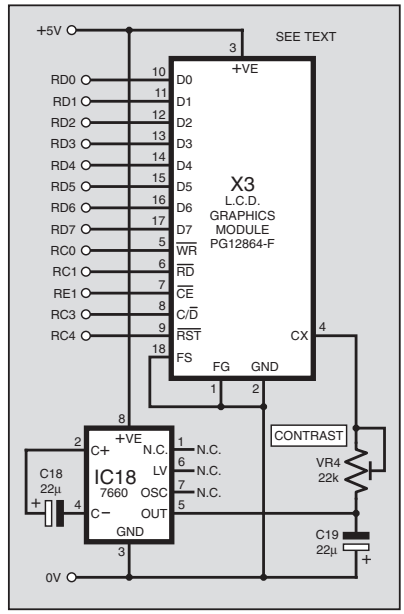


Fig.14. Circuit diagram for controlling a graphics l.c.d. display (see text).

12V, depending on load. At a maximum load of 45mA, the maximum output voltage is around 7·5V. The panel's output voltage is fed via diode D4 to the input of voltage regulator IC9.

The inclusion of diodes D4 and D5 ensures that the two power sources do not conflict with each other. Resistor R35 helps to prevent damage to the solar cell in the event of a short circuit at or following IC9.

Capacitor C15 at the input of IC9 provides preliminary smoothing to the source voltage(s). The one Farad (1F) capacitor, C16, on the output of IC9 is used as a voltage reservoir to minimise fluctuations in power when the solar cell is briefly shaded from the light source and the battery is temporarily removed for replacement. This capacitor has a maximum voltage rating of 5·5V, a limit which must never be exceeded.

Since the current drawn by the complete unit is about 25mA, it is not reasonable to rely only on the solar panel and the capacity of C16 for power. A battery should always be used to keep the circuit correctly powered.

If a rechargeable battery is used, it would be feasible to keep it recharged by the solar panel and a suitable current and voltage limiting circuit. This option will depend on the type of rechargeable battery used and no advice is offered – consult the battery manufacturer's datasheet.

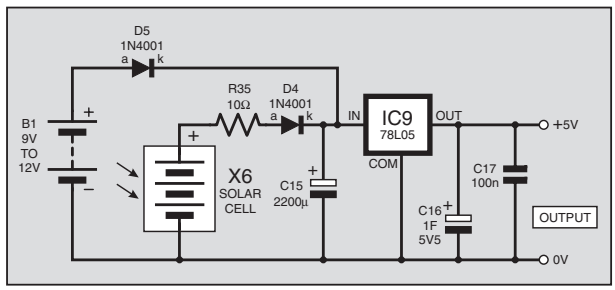
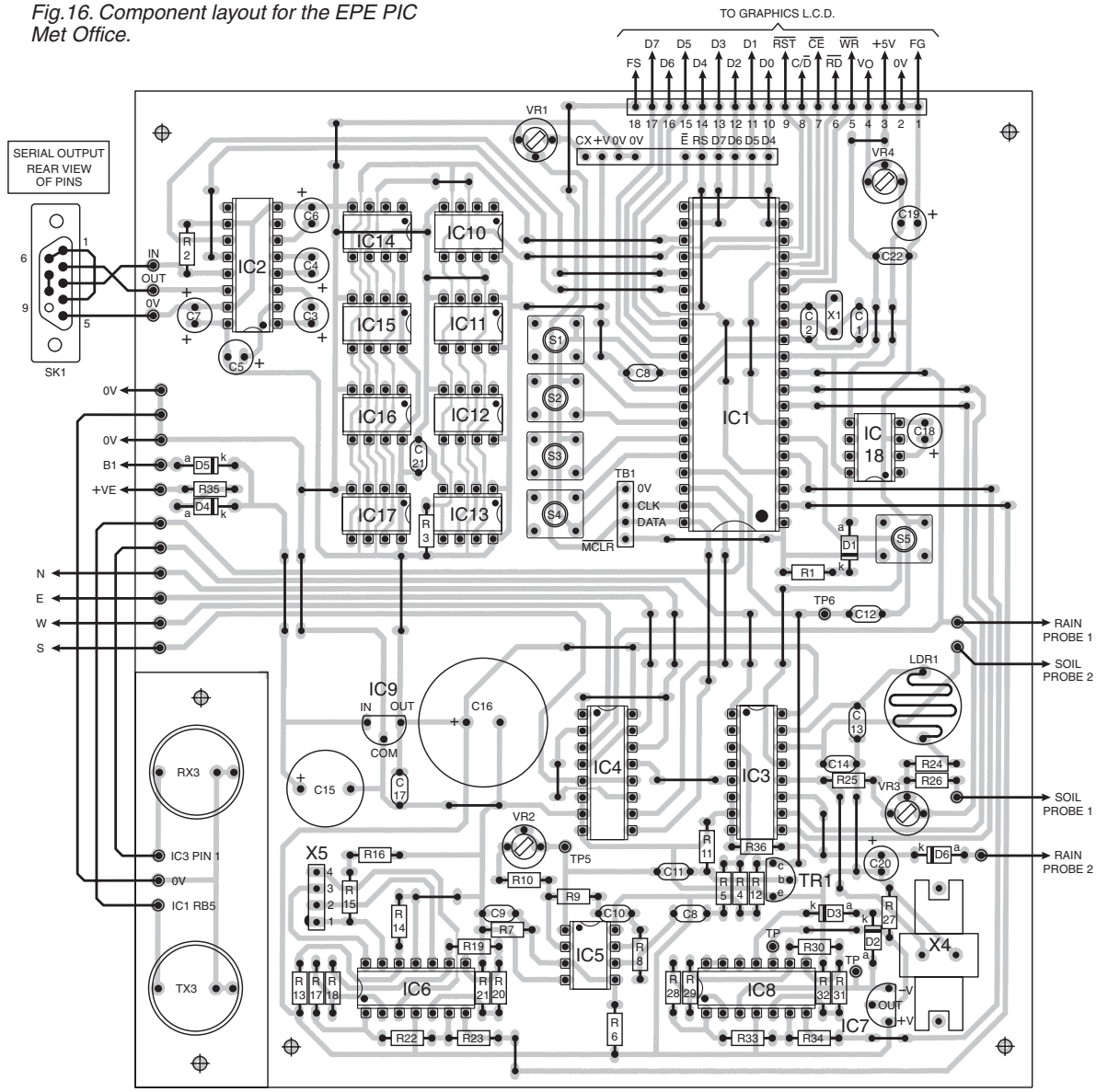


Fig.15. Power supply circuit diagram.

Fig.16. Component layout for the EPE PIC Met Office.



P.C.B. ASSEMBLY

The PIC Met Office is constructed on a single printed circuit board, whose component and track layout details are shown in Fig.16 and Fig.17. This board is available from the *EPE PCB Service*, code 402.

There is a small area at the bottom left of the board on which the two water level sensing transducers are shown. You have a choice here. One is to cut off this section and mount the transducers on it. Alternatively, the board can be left intact and the transducers mounted on a small off-cut of stripboard.

In either case, the sub-assembly is subsequently mounted on or above the rain water barrel, as discussed later.

It will be necessary to enlarge the two holes for the bolts which secure the humidity sensor (X4) at the bottom right of the board. Do this before starting assembly.

Insert and solder all the link wires, using 24s.w.g. tinned annealed copper wire. A reel of this should be part of any constructor's toolkit. Some links go under i.c. socket positions.

COMPONENTS

Approx. Cost Guidance Only **£95** *excl. solar panel, serial EEPROMS and hardware*

See SHOP TALK page

Resistors

R1, R24, R26	1k (3 off)
R2, R3, R5, R9, R11 to R13	10k (7 off)
R4	47k
R6, R7	100k (2 off)
R8	1M
R10	4k7
R14	3k3
R15	750Ω 1%
R16	56Ω 1%
R17, R19, R20, R22, R28 to R31, R33	10k 1% (9 off)
R18	2k2 1%
R21, R23	100k 1% (2 off)
R25	2M2
R27	18k
R32, R34	33k 1% (2 off)
R35	10Ω

All 0·25W 5% carbon film, or better, unless marked.

Potentiometers

VR1	10k min. preset, round
VR2	100k min. preset, round
VR3	1M min. preset, round
VR4	22k min. preset, round (see text)

Plus panel-mounting rotary, any value, plastic shaft, flat on one side (4 off, see Part 2 text)

Capacitors

C1, C2, C12	10p ceramic disc, 5mm pitch (3 off)
C3, C4	1μ radial elect, 16V (2 off)
C5 to C7	10μ radial elect, 16V (3 off)

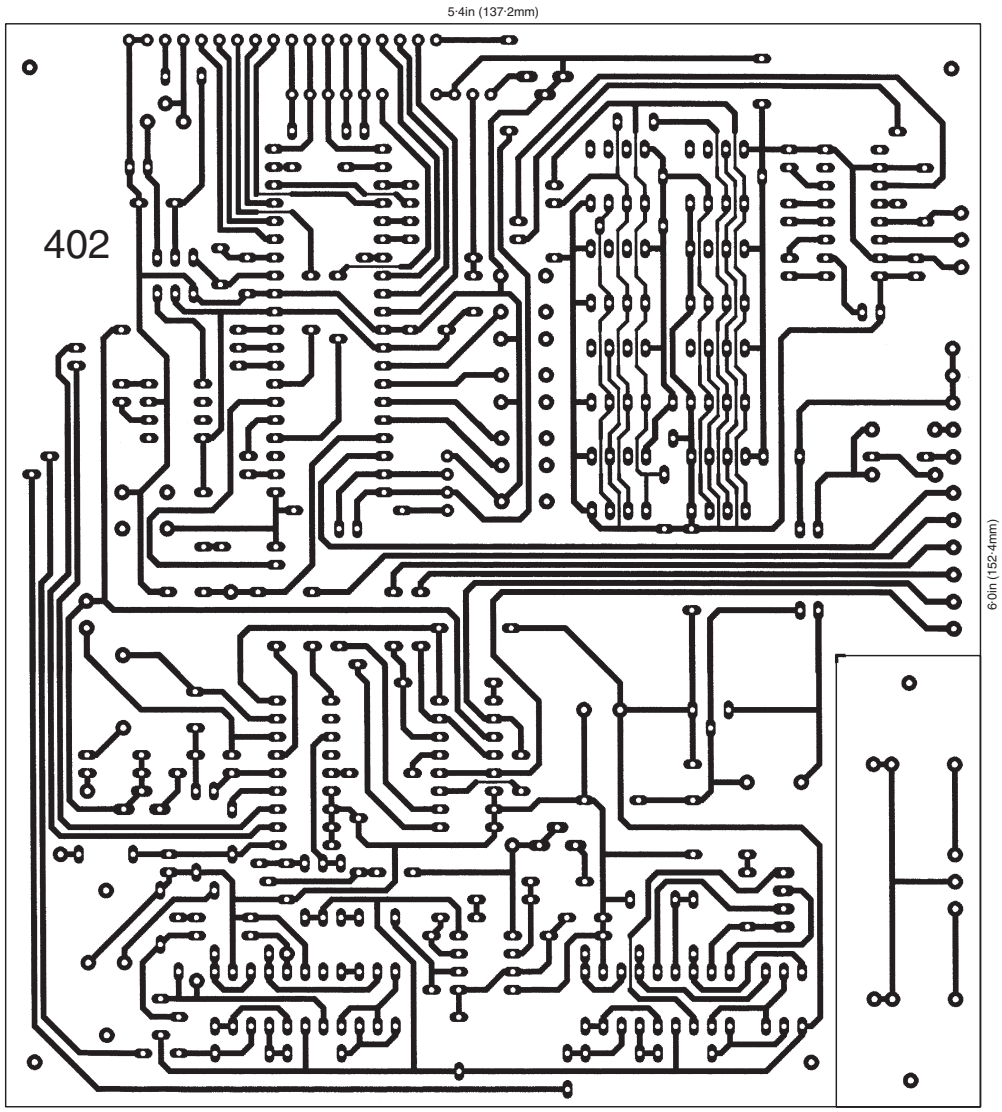


Fig.17. Copper foil master track pattern for the EPE PIC Met Office.

C8	100p ceramic disc, 5mm pitch
C9, C11, C14, C17, C21, C22	100n ceramic disc, 5mm pitch (6 off)
C10	1n ceramic disc, 5mm pitch
C13	220n, ceramic disc, 5mm pitch
C15	2200μ, radial elect. 25V
C16	1F computer back-up, radial, 5.5V
C18, C19	22μ radial elect. 10V (see text) (2 off)
C20	22μ radial elect. 10V

Plus 110p and 145p test capacitors (see text)

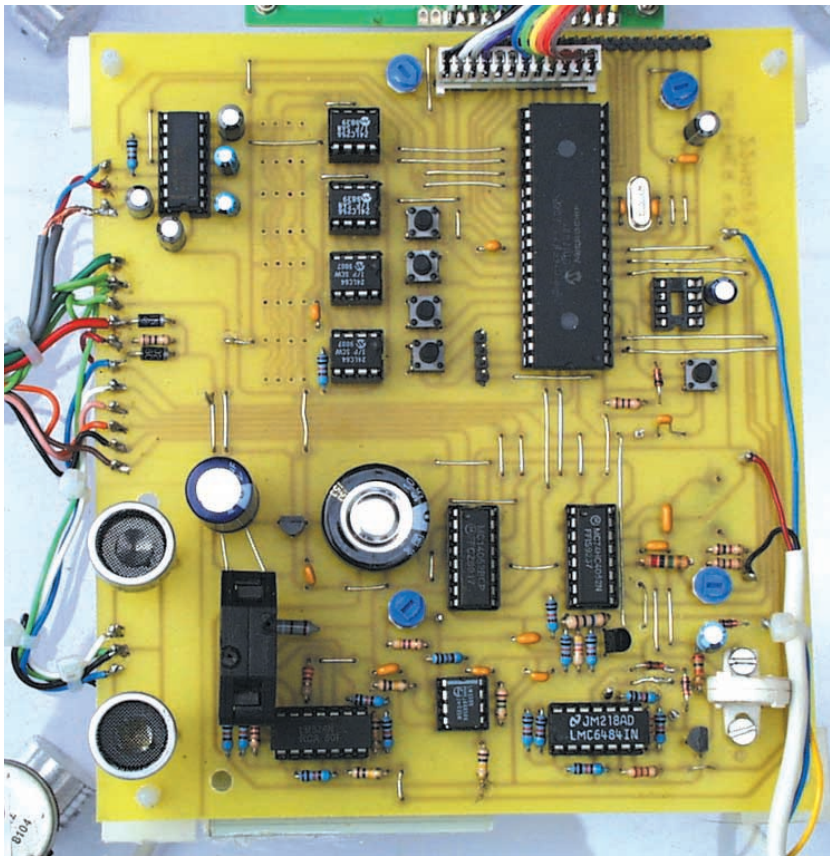
Semiconductors

D1 to D3	1N4148 signal diode (3 off)
D4, D5	1N4001 rectifier diode (2 off)
TR1	BC549 *npn* transistor
IC1	PIC16F877–20 microcontroller, pre-programmed (see text)
IC2	MAX232 RS-232 interface
IC3, IC4	74HC4052 2-pole 4-way analogue multiplexer (2 off)
IC5	LM358 dual op.amp
IC6	LM324 quad op.amp
IC7	LM35CZ
IC8	LMC6484 quad op.amp rail-to-rail
IC9	78L05 +5V voltage regulator, 100mA
IC10 to IC17	24LC256 serial EEPROM, 256 kilobit (8 off) (see text)
IC18	7660 voltage inverter (see text)

Miscellaneous

LDR1	ORP12 light dependent resistor
S1 to S5	min. push-to-make switch, p.c.b. mounting (5 off) (see text)
SK1	9-pin D-type serial connector, female, chassis mounting
X1	10MHz crystal
X2	2-line, 16 characters per line alphanumeric l.c.d. module
X3	PG12864-F graphics l.c.d. (not implemented – see text)
X4	Rapid 61-0960 humidity sensor
X5	SCC15A pressure sensor
X6	RS 194-098 solar panel (see text)
TX1 to TX3	40kHz ultrasonic transmitter (3 off)
RX1 to RX3	40kHz ultrasonic receiver (3 off)

Printed circuit board, available from the *EPE PCB Service*, code 402; 8-pin d.i.l. socket (10 off, see text); 14-pin d.i.l. socket (2 off); 16-pin d.i.l. socket (3 off); 40-pin d.i.l. socket; serial cable, length to as needed, connectors to suit PC, and 9-pin D-type serial, male, line mounting; 1mm pin-header strips; 1mm terminal pins, double-sided; materials for enclosure, see text; connecting wire; solder, etc.



See text regarding ultrasonic transducers at the left and the five unused i.c. positions.

Next insert the sockets for all the d.i.l. (dual-in-line) i.c.s, followed by the remaining components in ascending order of size. Do not insert the d.i.l. i.c.s or capacitor C16 until the correctness of the power supply has been proved. Also omit the humidity sensor as setting-up requires two test capacitors to be soldered in its position to establish the range timing factors.

Ensure the correct orientation of the electrolytic capacitors, transistor TR1, IC7, IC9 and the diodes. Note that C15 will need its leads bending to allow space for the pressure sensor.

Initially solder the l.d.r. light sensor to the p.c.b. by short off-board connecting wires. This facilitates testing. Ultimately the l.d.r. should be soldered on the *trackside* of the board, which will be mounted on a transparent cover trackside upwards. It is easiest to solder the pins if the l.d.r. body is held a few millimetres above the board.

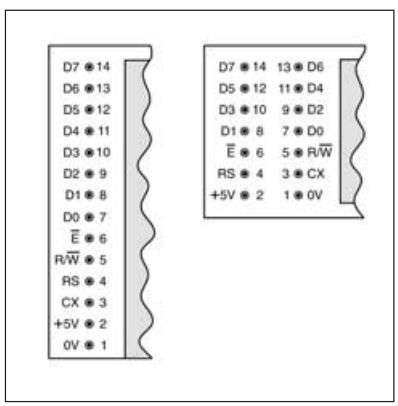


Fig.18. Typical l.c.d. module pinouts.

Do not connect the l.c.d. until first tests have been made. Typical pinouts are shown in Fig.18.

SOFTWARE FILES

Software, including source code files, for the PIC unit and PC interface is available on a 3·5in disk (order as PIC Met Office Disk) from the Editorial office (a small handling charge applies – see *EPE PCB Service* page) or it can be downloaded free from the *EPE* FTP site. The latter is accessible via the home page of the main *EPE* web site at **www.epemag.wimborne.co.uk**. Click on **FTP Site (downloads)** then in turn on **PUB** and **PICS**, in which page the files are in the folder named **PICMetOffice**.

This month's *Shoptalk* page provides information about obtaining preprogrammed PICs.

The PIC program (ASM) was written in a variant of TASM suited for use with *Toolkit TK3*, although the run-time assembly is supplied as an MPASM HEX file, which has configuration values embedded in it (crystal HS, WDT off, POR on, all other values off), plus EEPROM data.

Regarding the PC interface, if you have Visual Basic 6 (VB6) already installed on your machine, you only need to use files **Weather.exe**, **INPOUT.DLL** and **WeatherBeaufort.txt**. Unzip (if supplied zipped) and *copy* them into a new folder named **C:\PIC MET OFFICE**, or any other of your choosing on Drive C (the usual hard drive letter). The software does not require to be "installed".

If you do *not* have VB6, you will need three other files, **comdlg32.ocx**, **Mscomctl.ocx**, and **Msvbm60.dll**, held on our 3·5inch disk named Interface Disk 1, and in the Interface folder on the FTP site (they are also included with the *TK3* software, in **Disk2.zip**). These files must be unzipped and then copied into the same folder as the other PIC Met Office files.

For those who have the *TK3* programmer and wish to modify the author's PIC software to suit themselves, on-board programming connections are provided by the pins shown within the TB1 outline.

Diode D1 and resistor R1 are included to protect the 5V power line during programming download.

SOFTWARE NOTES

Note that as the PIC's ASM file is written in TASM, it is necessary to convert it to MPASM if you wish to modify the code via an MPASM-type assembler. *TK3* has the conversion routine built-in. Otherwise, program the PIC with the HEX code, which is already in the MPASM format.

It should also be noted that the VB6 program contains a serial transfer routine that is subject to copyright restrictions until a forthcoming PIC-to-VB6 serial interfacing facility from Joe Farr has been published. Until then, when certain key files will be released, readers with VB6 facilities cannot modify the author's PIC Met Office VB6 software.

This restriction does not affect the fully compiled and standalone PIC Met Office PC program, **Weather.exe**.

FIRST TESTS

Thoroughly check the assembly for wrongly positioned components and poor soldered connections, using a close-up magnifying glass.

Connect a power supply source of between 9V and 12V d.c. Immediately check that there is +5V present (within a few percent) at the output pin of regulator IC9. If not, disconnect the power and correct the cause of the problem, which could be due to IC9 being inserted the wrong way round (voltage too high), or by a solder short somewhere on the board (no output voltage).

Always disconnect the power before making any changes on the board.

Insert the preprogrammed PIC and connect the l.c.d., typical pinouts for which are shown in Fig.18.

Re-apply power and adjust preset VR1 until the display contrast is satisfactory. Initially a message of PIC MET OFFICE X EEPROM CHIPS is displayed briefly (which may not be seen unless the contrast has been adjusted), where X is replaced by the number of EEPROM chips detected (from 0 to 8).



Typical l.c.d. screen at switch on and Reset.

The screen then cycles through the sensor display modes, in order of humidity, soil moisture, light level, water level, wind speed and direction, temperature,



Example display showing current channel and sample count.

barometric pressure, a display showing all four wind factor counts, followed by CHAN/SAMPLE, showing where data samples are being stored to the serial memory chips. The cycle then recommences from humidity.

Except for the wind factors, on the top line the sensor's title is displayed at the left. At the right is the actual value sensed for that sensor, in hexadecimal. At the left of the bottom line is shown the processed value calculated in relation to various range values (preset by the user into the PIC's non-volatile EEPROM register).

At this time the displayed values will be meaningless until the full complement of i.c.s has been inserted and calibration values have been entered by various switches (see Part 2).

Pressing Reset switch S5 will cause the PIC to restart the program from the beginning. Pressing switch S2 will "freeze" the currently-displayed screen on that mode, allowing values to be observed each time they are updated. Pressing S2 again causes the cycle to continue.

LIGHT TEST

The light sensor can be tested first. Insert multiplexer IC3 and re-apply power. Position the l.d.r. to face the light.

Vary the amount of light falling on its sensitive face and observe how the displayed values change between each occasion that the Light mode screen is displayed. Make a note of the extreme values (in hexadecimal, as on the top line) when the l.d.r. is in complete darkness (cover it with a clump of dark cloth), and in maximum illumination (shine an anglepoise lamp or similar onto it). These values will be used later.

Ultimately, you will take the extreme values in full sunlight and at the light level which you regard as being darkness, and set the PIC's factors accordingly.



Example of light level sensor l.c.d. screen.

SOIL TEST

Initial soil moisture testing can be carried out using the probes of your multimeter and three plant pots, say 12cm diameter. Fill the pots with soil that is really dry, moderately damp and well saturated with water.

Clip the meter leads (without the meter!) to the designated points on the board. In turn, insert their probes at opposite sides of each plant pot. Note the extreme values between dry and saturated, but just observe the value for the moderately damp soil out of interest.



Example of soil moisture l.c.d. screen.

In the final setting-up you need to monitor soil that has the maximum moisture content you regard as satisfactory, and minimum moisture content which indicates that plant watering is required.

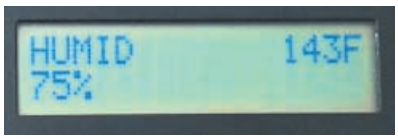
HUMIDITY TEST

As commented earlier, it is not realistic to assess atmospheric humidity content in relation to fully dry and fully saturated. Consequently another technique is used to establish the humidity sensing range.

The humidity sensor used has a stated datasheet capacitance range of 110pF to 145pF, representing a relative humidity (RH) range of 0% to 100%. These extremes are simulated by using capacitors in place of the sensor itself. Ideally they should have the best tolerance specification available, say 1%, although 5% will probably be satisfactory for this application.

First solder a capacitance of 110pF across the sensor's allocated pads on the board. This value may be obtained by using a capacitor of 100pF in parallel with one of 10pF.

Allow time for the temperature of the capacitors to stabilise following the heat of soldering. Then note the sampled value displayed on the l.c.d.



Example of humidity sensor l.c.d. screen.

Next solder a capacitance value of 145pF across the pads. The author used 100pF in parallel with two 22pF capacitors (also in parallel), ignoring the 1pF discrepancy. Allow cooling time, and then note the display reading.

These two readings represent the extreme 0% to 100% RH values. The range will not be precise of course, due to the tolerance and temperature stability of individual humidity sensors. but should be acceptable for this application. Adjustment to the values set into the PIC's data EEPROM can always be made later if you think the range deserves adjustment.

The humidity sensor itself can now be added to the board in place of the capacitors. Be very careful doing this as the sensor's leads are delicate. (In the prototype they actually broke off, requiring rigid wires to be soldered to the remaining stubs.)

Insert the leads into their holes, but do not solder them until the sensor's securing bolts have had their nuts tightened.

When power is re-applied, a value lying between the two extremes produced by the capacitors should be observed on screen. Lightly breathing on the sensor should cause the displayed value to change.

The use of preset VR3 was found to be unnecessary, set it to a midway position and ignore it.

Be aware that the sensor is slightly light sensitive.

TEMPERATURE TEST

The temperature sensor, IC7, can now be tested. First observe the displayed value on the screen. Then hold the sensor between your fingers to warm it. The displayed value should change in response.



Example of temperature sensor l.c.d. screen.

You can also monitor the sensor using a voltmeter. There are two points at which this can be done, across the sensor's output and negative terminals, for which test points have been provided on the board. The sensor's manufacturing characteristic, as said earlier, is a change of 10mV per degree Celsius. The voltage change can also be monitored between IC8c output pin 7 and the 0V line. The change observed here should be 100mV per degree Celsius. Be aware that there is a d.c. bias at the output of IC8c. Software takes care of compensating for this, with your help via the switches during setting up.

In the final setting-up, the displayed temperature display value can be set in conjunction with an accurate mercury-filled thermometer, or by reading the voltage across the sensor's output and –VE pins.

Through the use of 1% resistors at certain points in the amplifier, it is assumed that the output voltage change is linear with respect to temperature change. Consequently, the software should only require correction upwards or downwards, as described later, but the span range can also adjusted through software.

BAROMETRIC TEST

There are no workshop tests that can realistically be done on the barometric pressure sensor at this time. The final setting-up requires values to be read under known millibar pressure conditions. These can be obtained from weather forecasts or via the internet, or from an existing domestic barometer.

They can also be established by observing the readings when the PIC Met Office is taken between locations at known different heights (obtainable from a large-scale ordnance survey map). It is recognised that hills can be few and far between for those who live in East Anglia and Lincolnshire!

Setting-up of the barometer is detailed later.

NEXT MONTH

In the final part next month, testing the other sensors will be described, plus enclosure construction, the PC software and final setting up.

TECHNO-TALK ANDY EMMERSON

Connected Homes

No, not terraced houses but the notion of homes fully networked for home entertainment, automation and Internet access. Andy Emmerson reports.

PERHAPS it's a sign of the times that Microsoft's botched May announcement of the iLoo, a toilet with a wireless keyboard and extending, height-adjustable plasma screen for surfing the Net while you, er, do your other business, gained far more attention than BT's Home of Possibilities the month previously.

Nevertheless, the fact that both companies chose to make their announcements at about the same time indicates they see fully-wired homes as the way to go. So now is a good time to look at what's happening in this field and check out the trends, which bring together three separate strands – domestic networking, Internet-ready appliances and readily available broadband access.

As yet it is inappropriate to use the word *affordable* as most people will not consider these options to be so, but if the plummeting cost of computers and DVD players is anything to go by, low-cost "wired" living is not far off.

SATURATED

Forget your prejudices and incredulity when you read two years ago about fridges that could re-order food over the Internet, cookers that heated up the food when you email them just as you leave the office, music and the Web in every room of the house. It probably sounded as unlikely as personal helicopters for all, with a landing pad on every garage roof. But there are signs this is going to happen now, if only because the PC market is well-nigh saturated and appliance manufacturers are desperate to create new markets.

There's word of imminent release of ultra-desirable networked products from mainstream manufacturers such as Philips and Sony. More important, the emergence of agreed standards for interconnection of all these gadgets is virtually certain now.

At the *Ideal Home* exhibition this spring BT launched its Home of Possibilities concept, along with a set of new products as part of its vision for a networked home where, through the same broadband connection, every member of the household can work and play whenever they want. It will allow users to connect multimedia devices such as PCs, gaming consoles and media players throughout the house via a central hub, working from the same "pipe" and usable simultaneously and remotely.

BT concedes this is an important component of its strategy to grow the number of its broadband customers from one million this summer to five million in 2006. And BT expects the new products and services to generate sales of more than £100 million in 2004-05. The new products include:

- low-cost home monitoring service, costing £5 a month, which uses the Internet to alert customers to break-ins and emergencies via phone, text message or email
- home networking solution that links up to ten computers and gaming consoles in the home with no new wiring required
- digital media player allowing you to listen to streamed audio from your PC anywhere in the house
- partnership with Microsoft to launch Xbox live, enabling users to play opponents anywhere in the world in real time.

WIRED TO GO

Big names such as Philips and Sony have "wired" products ready to hook into home networks too, although both use a PC as intermediary. Philips' digital multimedia receiver uses a wi-fi connection to the PC, through which audio and video streaming Internet content is conveyed to audio and video products. Styled like a conventional hi-fi separate, the unit is designed to augment existing A/V systems.

From Sony comes the Network Media Receiver, which connects to a TV or stereo amplifier to deliver broadband content from the Net. A major limitation is the need to use a Sony PC running proprietary software. Sharp and other manufacturers have announced audio products that hook up to the Internet to download MP3 files, whilst Apple's new iTunes service looks like providing a huge choice of legal, low-cost music.

If these hardware products don't sound exactly like the best thing since sliced bread, it's clear nonetheless that more sophisticated and flexible offerings cannot be far off. Bullish comments show these manufacturers are determined to develop this arena with Sony aiming to make the "ubiquitous broadband network" a reality in people's homes.

Let's hope too that Scott Levitan, a brand director with Philips, is not creating a hostage to fortune when he states, "We will succeed in convergence and the connected home by putting the consumer's requirements firmly at the centre of our efforts in this area".

KILLER AP

A mischievous translation of the last statement might be that the killer application for connected homes has not yet materialised but it may not be far off. Horrendous tales of power outages in California remind us how vital energy efficiency is and if networked control of domestic devices could reduce heating and lighting bills significantly, then it will sell itself.

A clear move in this direction comes from a Japanese government-sponsored initiative to promote and standardise home networking and energy management through smart appliances. Energy conservation is a key objective of this general-purpose system that requires no special rewiring for applying to existing as well as new homes and that can easily control a wide range of devices. It has spawned the largest home networking forum in the world, embracing 120 member companies internationally, and is known as the Echonet consortium (echo as in ecology – you work it out!).

So far so good but is this truly sexy? Well, not really but how about this for the ultimate home of the future? Forget wired-up (or wireless) entertainment delivery for a moment and consider a more radical glimpse of the home of the future. Its name is the Vos Pad (crazy name, crazy place) and it's "a blueprint for future living" according to its exponents, Vos Solutions. The company has integrated the latest technologies within a design framework to create a truly 21st century living space.

LIGHT ENTERTAINMENT

It is, for instance, the world's first apartment lit solely by light emitting diodes, with its ambience controlled via a custom-built computerised system that operates the lighting. The level and colour of the lights in different areas can be changed instantly and the window blinds are also remote-controlled.

The Vos Pad has an integrated home entertainment system with plasma TV screens and surround sound technology, the screens being embedded into the kitchen, bathroom and lavatory walls (no more missing bits of your favourite programme during personal needs breaks!). If that's not your idea of entertainment, then the Vos Pad also features a fully programmable digital grand piano (every home should have one!).

The bathroom features a spectacular l.e.d.-illuminated spa bath and side-lit shower screen that changes colour. The Vos Pad's stainless steel fitted kitchen has integrated appliances, featuring side lit colour changing glass worktops. Limestone flooring is fitted throughout, with all heating under the floor.

Entry is controlled by fingerprint verification system, with the whole thing representing a demonstration of the positive use of technology and an example of the effective integration of design and modern scientific developments in an environmentally conscious manner.

Like BT's Home of Possibilities, the Vos Pad is a statement of concept at the moment, but it does exist, as a luxury apartment adjacent to Chelsea Harbour, London, with riverside views. To save you the journey, you can also visit it on the Web at **www.thevospad.com**.

More on this next month.



INGENUITY UNLIMITED

Our regular round-up of readers' own circuits. We pay between £10 and £50 for all material published, depending on length and technical merit. We're looking for novel applications and circuit designs, not simply mechanical, electrical or software ideas. Ideas *must be the reader's own work* and **must not have been submitted for publication elsewhere.** The circuits shown have NOT been proven by us. *Ingenuity Unlimited* is open to ALL abilities, but items for consideration in this column should be typed or word-processed, with a brief circuit description (between 100 and 500 words maximum) and full circuit diagram showing all relevant component values. **Please draw all circuit schematics as clearly as possible.** Send your circuit ideas to: *Ingenuity Unlimited,* Wimborne Publishing Ltd., 408 Wimborne Road East, Ferndown Dorset BH22 9ND. (We **do not** accept submissions for *IU* via E-mail.) Your ideas could earn you some cash **and a prize!**



WIN A PICO PC BASED OSCILLOSCOPE WORTH £586

- 100MS/s Dual Channel Storage Oscilloscope
- 50MHz Spectrum Analyser
- Multimeter • Frequency Meter
- Signal Generator

If you have a novel circuit idea which would be of use to other readers then a Pico Technology PC based oscilloscope could be yours. Every 12 months, Pico Technology will be awarding an ADC200-100 digital storage oscilloscope for the best IU submission. In addition, a DrDAQ Data Logger/Scope worth £69 will be presented to the runner up.

Audio Noise Generator – Roaring Forté

THE circuit shown in Fig.1 generates an audio noise voltage of between 3V and 5V peak-to-peak, depending on the "noisiness" of Zener diode D1.

The noise voltage produced across the Zener is amplified by the two-stage op.amp circuit, providing a voltage gain of about 1000, which produces an adequate output voltage level. The op.amp used is an LM833, although almost any dual op.amp should do the job.

The choice of Zener diode affects the output amplitude – it was found that 6V8, 7V5 and 8V2 Zeners usually gave a decent output voltage (above 1V p-p) but the few 5V6 Zeners tried were all virtually noise free.

The Zener voltage also affects the d.c. operating point of the op.amps. Too high a voltage (or too noisy an 8V2 Zener) can produce asymmetrical clipping of the output waveform.

P. Tomlinson, Hull, East Yorkshire

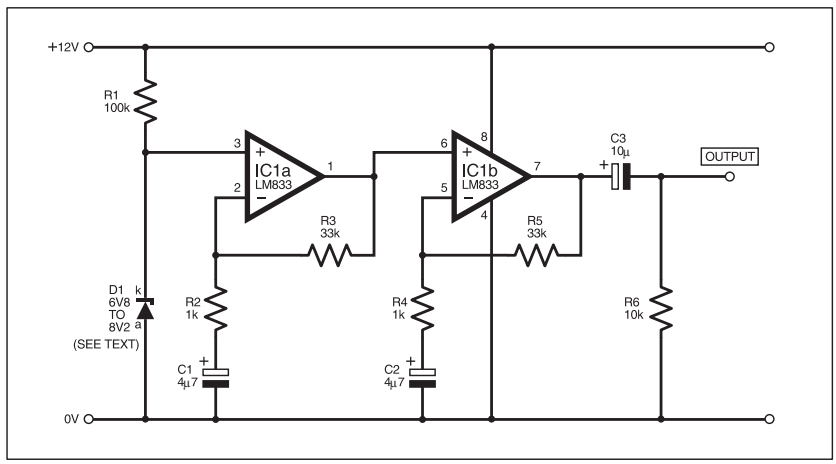


Fig.1. Circuit diagram for the Audio Noise Generator.

Day-Night Switch – Banishing Darkness

THE Day-Night Switch in Fig.2 uses the popular LP2950CZ-5.0 micropower regulator (IC1) to switch a 5V relay as night-time falls. Alternatively, if the light dependent resistor (l.d.r.) R1 and potentiometer VR1 are reversed, this switches the relay when day breaks. Potentiometer VR1 (wired as a variable resistor) is used to set the potential at IC1's adjust (ADJ) pin, and consequently the light level at which switching occurs.

The circuit works on the simple principle that the potential at the ADJ pin tricks the regulator into thinking it should shut down, or alternatively to power up. When in the off state, the regulator (excluding the potential divider formed by R1, R2 and VR1) typically draws 200µA.

Besides being virtually fool-proof, the circuit offers a significant advantage over a standard day-night switch using a transistor to switch a relay. Consider that IC1's ADJ pin has a very low ground current (typically 75µA). This makes it possible to use the circuit with a high value potential divider (up to and exceeding 200kΩ), which opens the possibility for using a thermistor, as well as other devices of a higher resistance, in place of the l.d.r.

In the case of a thermistor, this principle could be used to build a very simple fire alarm or thermostat. Note that the value of VR1 would then need increasing accordingly.

Other three-pin micropower regulators are likely to work in place of IC1. Also, different input voltages may work equally well. The relay's coil resistance should be greater than 50Ω.

Thomas Scarborough, Cape Town, South Africa

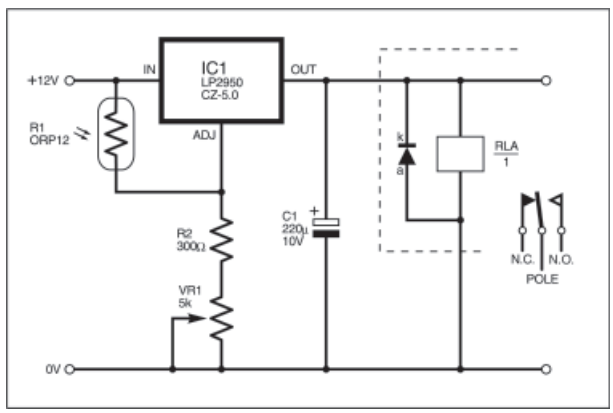


Fig.2. Circuit diagram for the Day-Night Switch.

INGENUITY UNLIMITED

BE INTERACTIVE

IU is *your* forum where you can offer other readers the benefit of your Ingenuity. Share those ideas, earn some cash and possibly a prize!



MASTER/SLAVE INTERCOM



OWEN BISHOP

This short collection of projects, some useful, some instructive and some amusing, can be made for around the ten pounds mark. The estimated cost does not include an enclosure. All of the projects are battery powered, so are safe to build. In a few cases where the project is to be run for long periods, power may be provided by an inexpensive mains adaptor.

An intercom has many uses around the home and office, including acting as a baby alarm. This simple low-cost circuit operates on the Master/Slave principle. This is a half-duplex system, in which there is communication in both directions, but in only one direction at any one time. This helps to make the circuit simple and cheap, and means that only a single pair of wires is needed to connect the stations.

One station is the Master, and controls the direction in which messages pass. The other station is the Slave and consists of no more than a loudspeaker, which functions as a microphone or as a speaker, depending on how it is switched into the circuit by the Master station.

HOW IT WORKS

The complete circuit diagram for the Master/Slave Intercom is shown in Fig.1. All of the circuit except for loudspeaker LS2 is housed at the Master station.

The circuit comprises two amplifiers, each of which has different characteristics and function. When switch S2 is set as shown, loudspeaker LS1 is acting as the microphone for the Master station, and LS2 is acting as a true loudspeaker for the Slave station. The action of the circuits is as follows:

Input amplifier

The amplifier through which speech is input from the loudspeaker acting as a microphone is configured in what is known as the common base transistor format. It is based on transistor TR1, which has its base (b) terminal held at a fixed voltage of 2·4V, set by the values of R2 and R3. This is held steady by C2.

When someone speaks into speaker LS1, the movement of the speaker coil in the field of the speaker magnet generates a small signal (amplitude 1mV or less). This passes through capacitor C1 to the emitter (e) of TR1. Thus, the signal is applied between emitter and base. The output is seen as a signal at the collector (c). Here the signal is between collector and base. Because the base is common to both the input and output signals, the amplifier is called a common base amplifier.

Without going into the detailed operation of the amplifier, we can list its characteristics as:

- High voltage and power gain
- No current gain
- Low input impedance
- Medium output impedance

The low input impedance makes it specially suitable for accepting the signal from a speaker which, having a coil resistance of only a few ohms, has a very low output impedance. In order to get the signal across to the transistor, we need an amplifier with low input impedance. A common base amplifier is specially suited for this purpose.

The amplifier also provides the first stage of voltage amplification, an important function because of the low amplitude of the original signal. Preset VR1 is adjusted so that the voltage at the collector of TR1 is at the mid-point (3V) when there is no signal. This makes it possible for the signal to swing the voltage up and down without distortion.

Low-power audio amplifier

IC1 is a single audio amplifier in an 8-pin package. It is capable of delivering an output of 250mW into an 8Ω speaker when running on a 6V supply. This is

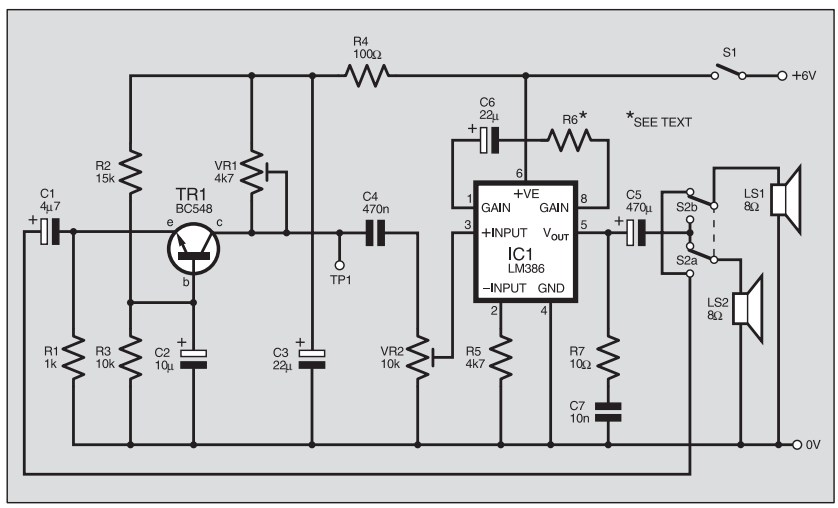


Fig.1. Full circuit diagram for the Master/Slave Intercom.

ample output for an intercom system. Its gain is internally set at 20 but can be increased by providing feedback from pin 8 to pin 1 through R6 and C6. Suitable values are:

Gain	R6
20	infinite (omit R6 and R7)
50	680Ω
100	180Ω
200	0Ω (use wire link for R6)

The volume of sound is also controlled by VR2 which can tap off a variable proportion of the output of TR1. The schematic shows this as a preset potentiometer. However, if you prefer to be able to increase and decrease the volume in operation, solder wires to the three pads allocated for VR2 and run these to a rotary potentiometer mounted on the case of the Master Station.

One problem with circuits of this sort is that the large fluctuating current drawn by the sounding loudspeaker can cause appreciable variations in the voltage on the supply rail. These voltage changes affect the operation of the common base amplifier. The circuit goes into oscillation, producing a sound known as "motor-boating" from the loudspeaker.

To prevent this from happening, there is a lowpass filter (R4/C3) on the supply to TR1. A steady supply current passes through R4 with only a slight drop in voltage, while C3 suppresses the variations in the voltage caused by currents through the loudspeaker. If motor-boating gives trouble, try increasing the value of C3. Test point TP is useful when setting up the system.

COMPONENTS

Approx. Cost Guidance Only **£10**
excl. power supplies, cases & loudspeakers

See SHOP TALK page

Resistors

R1	1k
R2	15k
R3	10k
R4	100Ω
R5	4k7
R6	optional (see text)
R7	10Ω

All 0·25W, 5% carbon film.

Potentiometers

VR1	4k7, min. preset, horizontal open skeleton or round (see text)
VR2	10k, min. preset, horizontal open skeleton or round, or panel mounting (see text)

Capacitors

C1	4μ7 radial elect. 10V
C2	10μ radial elect. 10V
C3	22μ axial elect. 10V
C4	470n metallised polyester film
C5	470μ radial elect. 10V
C6	22μ axial elect. 10V (see text)
C7	10n metallised polyester film

Semiconductors

TR1	BC548 *npn* transistor
IC1	LM386 audio power amplifier

Miscellaneous

LS1, LS2	min. loudspeaker, 8Ω, about 57cm dia. (2 off)
S1	s.p.s.t. min. toggle switch
S2	d.p.d.t. min. toggle or slider switch

Printed circuit board, available from the *EPE PCB Service*, code 407 (Intercom); plastic case (2 off, see text); 1mm terminal pins (7 off), 8-pin i.c. socket, light-duty single-core connecting wire; light-duty multicore twisted pair for connecting stations; 3·5mm mono jack plug and socket (2 off, see text).

CONSTRUCTION

The component positioning and p.c.b. track layout details for the Master/Slave Intercom are shown in Fig.2. This board is available from the *EPE PCB Service*, code 407 (Intercom).

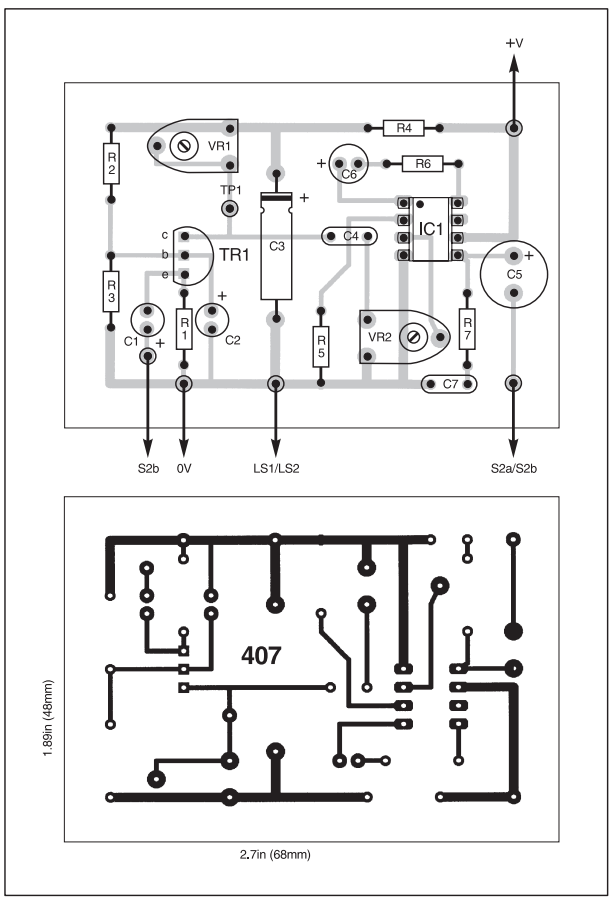
Assemble the board in order of ascending component size, and use a socket for IC1. The board allows for preset VR1 and VR2 to be round or open skeleton types (as just said, VR2 could also be a panel mounting rotary carbon type).

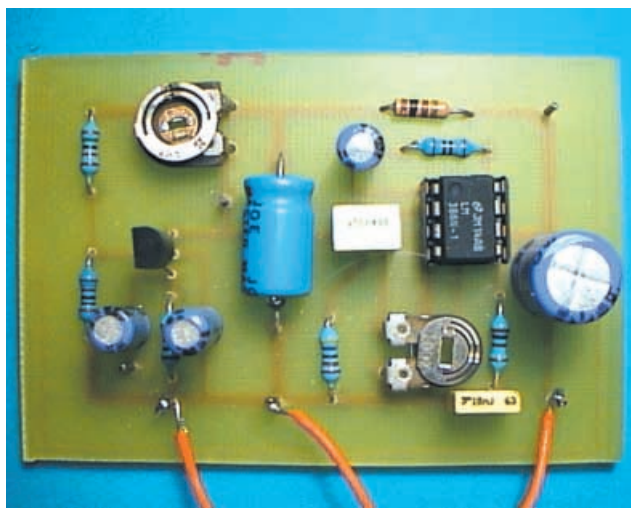
Using a hand magnifier, check the soldered side of the board to see that there are no dry solder joints and no threads of solder bridging between tracks.

ASSEMBLY

The project requires two boxes, each large enough for mounting the speakers. It is essential for the speakers to be firmly attached to their boxes and for the boxes to be closed in at the rear. If this is not done there will be an appreciable loss of volume.

A twisted pair of light-duty wires connects the stations. Fig.3 shows the wiring details. To save costs, it is possible to solder the ends of the wires directly to LS2 and to the terminal pins on the circuit board. However, it is more convenient if





Completed prototype Intercom circuit board.

Fig.2 (left). Printed circuit board component layout and full-size copper foil master for the Master/Slave Intercom.

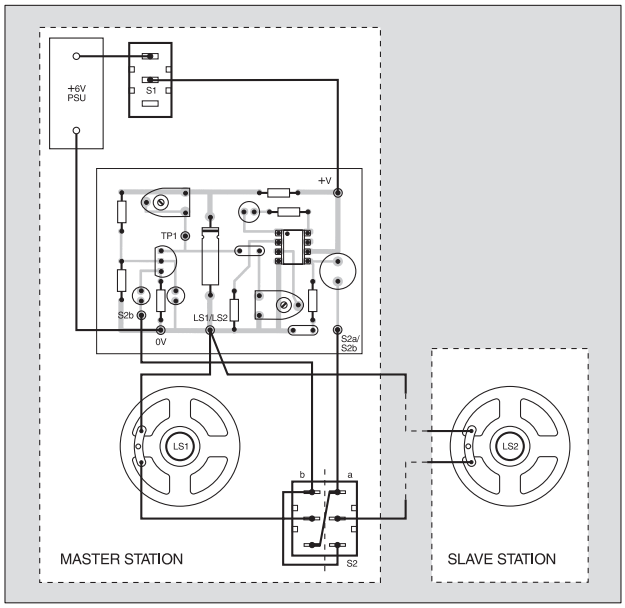
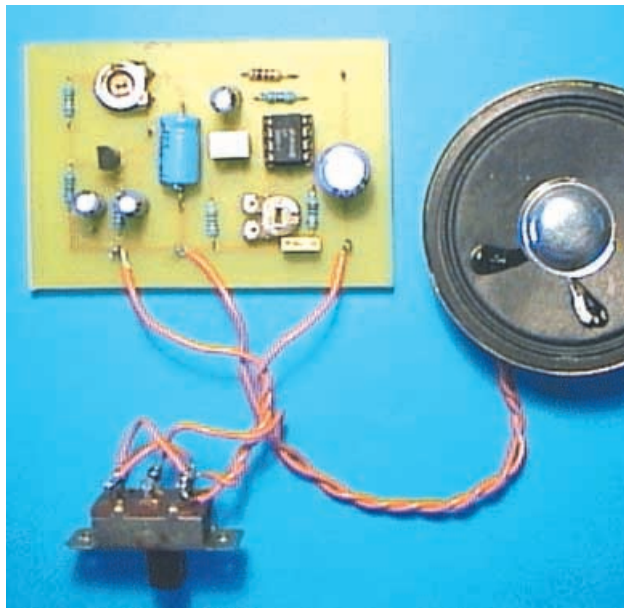


Fig.3. Interwiring from the Master Station to off-board components and Slave Station speaker.



Master Station circuit board and off-board components, except On/Off power switch.

jack plugs terminate the wires, with sockets mounted on the boxes. Also mounted on the box of the Master station are the power switch (S1), and the double-pole double-throw switch Master/Slave Talk switch (S2).

A 6V battery can power the project but this is suitable only if it is switched on for short periods. For longer periods, when used as a baby alarm for example, it is better to use a plugtop mains p.s.u. (power supply unit). It should supply 6V d.c. at up to about 500mA. The unregulated type is suitable and is cheaper.

To set up the system, connect a voltmeter to the 0V pin and to test point TP1. Adjust VR1 until the meter reads 3V. The circuit is then ready for operation. □

ELECTRONIC TWO-UP



Chance your luck with this novel game.

TWO-UP is a traditional Australian gambling game played everywhere from the remote outback to the glitzy casinos of the major cities. The game is played in a Ring, a circular fenced area crowded around by the participants. In the bush, if they are lucky, the players are protected from the burning sun by a corrugated iron roof.

The game is run by the Ringkeeper, who invites one of the participants to be the Spinner. The Spinner holds a wooden device, the Kip, in which are placed two coins. The players lay their bets on the table, then the Spinner flips the Kip. This action projects the coins into the air and they fall to the dusty floor of the outback Ring.

The coins may fall in one of three ways. As might be expected, two heads uppermost is Heads, and two tails uppermost is Tails. One of each is Odds. The probabilities are 25% for Heads and for Tails, and 50% for Odds.

The Spinner wins if they spin three consecutive Heads before spinning either Tails or five consecutive Odds. If the Spinner manages this successfully, they win at seven-and-a half to one. If the Spinner is unsuccessful, the game continues with someone else volunteering as Spinner.

But this is not all. While the Spinner is trying to throw three Heads in a row, the other players are busily betting Heads or Tails on each spin. They are paid "evens" if they win. If the throw is Odds their bet remains on the table for another spin, but otherwise they lose their stake. After five consecutive Odds all stakes are lost.

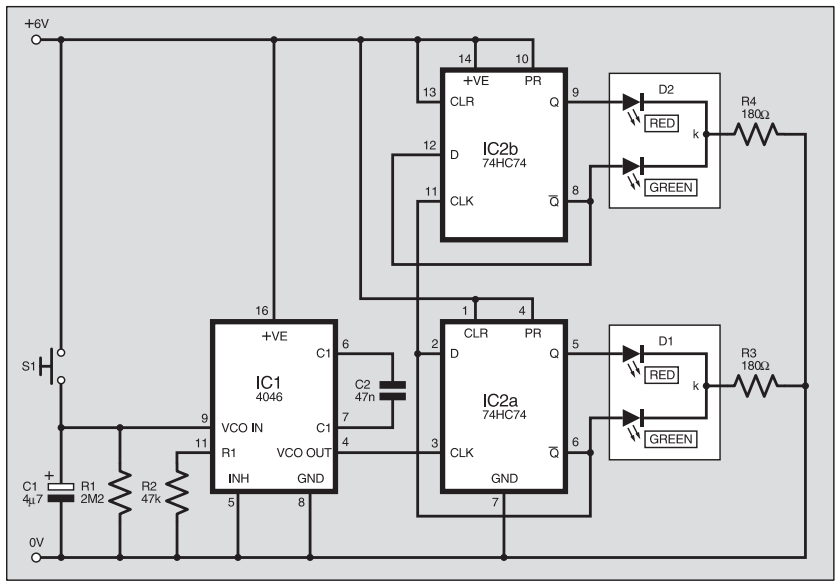


Fig.1. Complete circuit diagram for the Two-Up gambling game

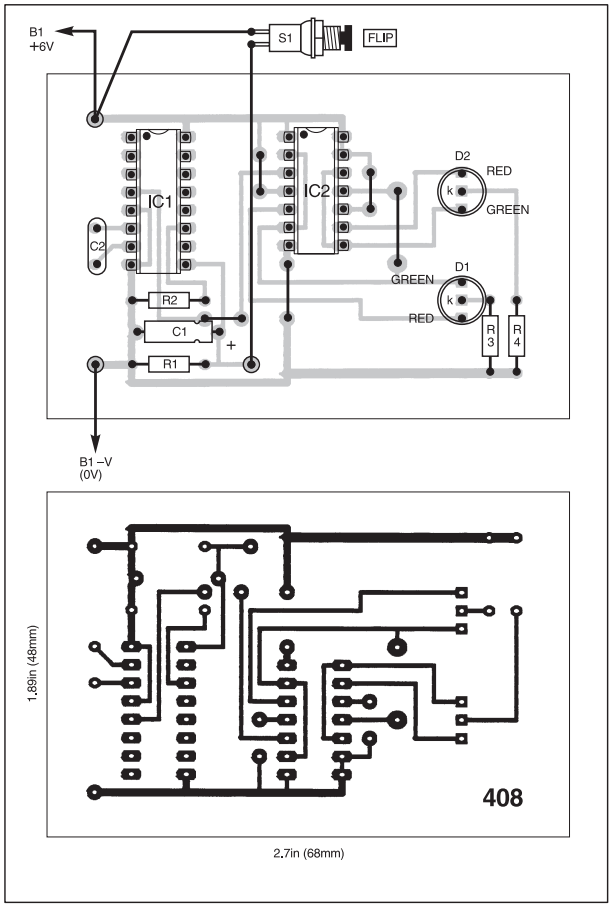
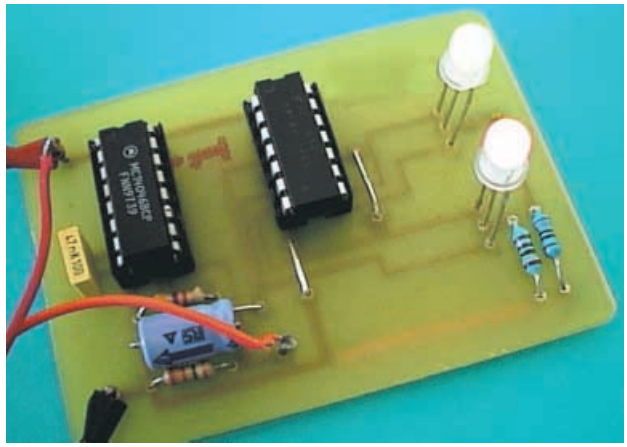


Fig.2. Component layout and full-size copper foil master pattern for the Two-Up guessing game.



Component layout on the Two-Up circuit board. Note the bicolour l.e.d.s are three-pin types.

BICOLOUR L.E.D.S

In this electronic version of Two-Up, the coins are each represented by a bicolour l.e.d. This glows red for Heads or green for Tails. The full circuit diagram is shown in Fig.1.

A type 4046 phase-locked loop, IC1, is configured as a voltage controlled oscillator (VCO). To start the l.e.d.s flashing, the Spinner presses and releases switch S1. This charges capacitor C1, so providing a 6V input to IC1 at pin 9. With the values of the timing components, capacitor C2 and resistor R2, specified, the VCO runs at a little over 700Hz.

However, when the switch is released, the charge on C1 gradually leaks away through R1, taking about 10 seconds to fall to zero. During this time the frequency of the output of the VCO slowly falls from 700Hz to zero.

The output signal from IC1 pin 4 is fed to the clock input of IC2a, which is used in conjunction with IC2b to form a 2-bit counting chain consisting of two D-type flip-flops. The outputs from the two counters run through the binary sequence 00, 01, 10, 11, repeating.

The outputs of the first flip-flop, IC2a pins Q and $\overline{Q}$, are connected to bicolour l.e.d. D1. This contains two l.e.d.s, one red and one green, with their cathodes connected to a common pin. As the flip-flop changes state, the output at $\overline{Q}$ is always the opposite of that at the Q output. The result is that either the red l.e.d. or the green l.e.d. is turned on, but never both together.

The $\overline{Q}$ output is also fed to the second counter, IC2b, to give the second digit of the binary sequence, flashing the red and green l.e.d.s of D2 at half the rate of D1.

PLACE YOUR BETS

At first, when capacitor C1 is fully charged, the rate of flashing is so high that the eye merges the colours and the l.e.d.s appear to glow with a yellowish light. Eventually, as the frequency falls, the l.e.d.s can be seen to be flashing red and green, running through the sequence green-green, green-red, red-green and red-red. In this way the sequence Tails-Odds-Odds-Heads is produced.

As the voltage on C1 drops, the rate of flashing falls more and more slowly, and suspense heightens as the players try to "will" the circuit to stop at a winning combination. At the end, the changes in state come a few seconds apart. Still, there is no telling what the final state will be, so this provides the random element of the game. It also combines the excitement of Two-Up with the suspense of Roulette. Customarily, it is assumed that the game is ended if 10 seconds has passed without a change in the colours, and then the bets are paid or lost.

CONSTRUCTION

The component positioning and track layout details for the Two-Up game are shown in Fig.2. This board is available from the *EPE PCB Service*, code 408 (Two-Up).

Assemble the board in order of ascending component size, and use sockets for IC1 and IC2. The link wires can be from resistor offcuts. Ensure that the l.e.d.s are the correct way round, as must be the i.c.s, but do not insert them until after the board has been fully checked.

Then insert IC1 in its socket. Check the rise and fall of the voltage at pin 9 as you press and release switch S1. If you have a multimeter with a frequency readout, check the output at pin 4. It should rise almost instantly to just over 700Hz, then slowly fall to zero after S1 is released.

Now insert IC2 in its socket and monitor the signal at pins 1 and 2 (360Hz when S1 is pressed), and pins 12 and 13 (180Hz). If there is no signal at these pins check that pins 1, 4, 10 and 13 are all at +6V. These are the Clear and Reset inputs and the flip-flops do not run if these inputs are not high.

Finally, check that the l.e.d.s shimmer and flash as described. After that, mate, chance your luck in the Two-Up Ring! □

COMPONENTS

Resistors

R1	2M2	
R2	47k	
R3, R4	180Ω	(2 off)

See SHOP TALK page

Capacitors

C1	4μ7 axial elect. 16V
C2	47n ceramic disc, 5mm pitch

Semiconductors

D1, D2	bicolour l.e.d., 3-pin version (2 off)
IC1	4046 phase-lock loop
IC2	74HC74 dual D-type flip-flop

Miscellaneous

S1	push-to-make switch

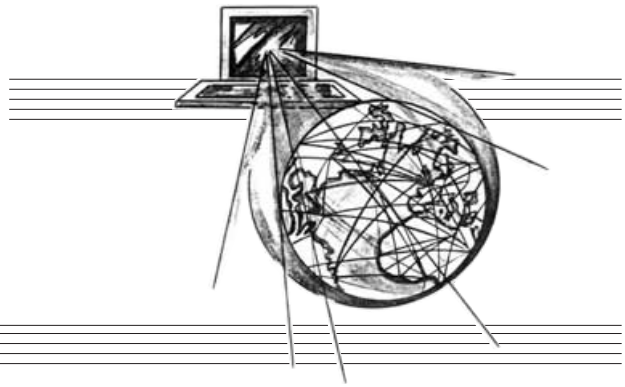
Printed circuit board, available from the *EPE PCB Service*, code 408 (Two-Up); 14-pin d.i.l. socket; 16-pin d.i.l. socket; 1mm terminal pins; connecting wire; solder, etc.

Approx. Cost Guidance Only **£7** *excl. case & batts.*

SURFING THE INTERNET

NET WORK

ALAN WINSTANLEY



New web site

USERS of our UK web site at **www.epemag.wimborne.co.uk** will have noticed a radical change in the last few weeks, with the launch of a brand new design. It is intended to co-ordinate with *EPE Online*, our Internet-only edition (**www.epemag.com**), and it has been completely redesigned from the ground up. This month's *Net Work* is a walk-through of the new site and what it has to offer.

Each page contains a simple navigation panel that carries a series of buttons:

- ***Monthly Features***
- ***Subscribe Now***
- ***Online Shop***
- ***Project Index***
- ***Chat Zone***
- ***Net Work***
- ***More Info***
- ***Contact Info***

Additionally there are separate clickable links for a forthcoming new *Downloads* page, and also there's the *Resources* page as before. Probably the most important page for regular constructors will be the ***Projects Index*** page. This is a chronological listing of each issue, with a brief outline of contents. The Projects main page shows the current year, and there are links for the previous five years as well. Use either the nav-panel button or the separate link in the body of the home page to launch the Projects Main Page.



Part of the Home Page of the new EPE web site – note the navigation panel (top left). The Project Index page replaces the "Recent-Issue" page and contains any Please Take Note *for projects, dating back five years (no less!)*

By clicking on an individual month, a pop-up window opens that contains colour photos of each month's projects. In response to popular request, any corrections or updates to projects are now added to the web site as soon as they arise. A small icon against a project name highlights the fact that a *Please Take Note* amendment has been published, details are also given in the pop-up window.

The Resources page contains the *Basic Soldering Guide* which will be redesigned and brought up to date. Other useful articles that we published over the years are also linked on the Resources page; we hope to expand this range in due course.

Downloads Page

One of the most important functions that our Internet presence has is to make available our comprehensive listing of PIC microcontroller source codes for download. *EPE* was the first magazine in the world to do this for free, and a large number of files have accumulated over time on our FTP server (type **ftp://ftp.epemag.wimborne.co.uk/pub** into your web browser). However, it would be true to say that, in spite of FTP being a common enough protocol, many readers have struggled to access these files, sometimes due to inexperience (as reflected in the often intemperate emails received!), or possibly due to browser compatibility problems. Often there has been nothing wrong that decent FTP freeware wouldn't cure.

Although the technical issues seem to have eased somewhat, a new Downloads page is currently under development, which will form a web-based front-end of all our downloadable PIC source files. At last, you will be able to download files directly onto your machine through a web page, though you can still use FTP as usual if preferred. There will still be a link to the PIC Mirror site kindly maintained by Thomas Stratford, available as a second source of our files.

Over at the *Chat Zone* message board, this has had a minor makeover and hopefully the technical problems associated with the navigation panel will be resolved by the time you read this. The "Acceptable Use Policy" has also been reinforced in some areas, in line with our desire to ensure that the forum remains a friendly, tolerant and welcoming place to help electronics enthusiasts of all age groups from around the world. Once again, our thanks go to all those regulars who help out with the message board.

There are also links to the *EPE Online Shop*, which is the UK-based service that provides back issues, project p.c.b.s, books, CD-ROMs, videos and more. This too is being updated shortly. Further developments are in the pipeline including a site-wide Search facility and the introduction of banner adverts for a select number of electronics suppliers.

We are all very proud to be able to bring you this much-improved online resource, so why not click over to our web site now and see what's happening?

In next month's *Net Work*, it's back to the topic of broadband, when I look at what's available to bandwidth-hungry users who find themselves beyond the reach of mainstream broadband services. You can email me at **alan@epemag.demon.co.uk**.



Each month's magazine projects are summarised in a pop-up window, available from the Projects Main Page. Click a month to view.

EVERYDAY PRACTICAL ELECTRONICS

BACK ISSUES

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MAY '02

PROJECTS ● PIC Big-Digit Display ● Simple Audio Circuits – 1 ● Freezer Alarm ● Washing Ready Indicator.
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JUNE '02

PROJECTS ● Biopic Heartbeat Monitor ● Frequency Standard Generator ● Simple Audio Circuits – 2 ● World Lamp.
FEATURES ● Teach-In 2002 – Part 8 ● Interface ● New Technology Update ● Circuit Surgery ● Ingenuity Unlimited ● Net Work – The Internet Page.

JULY '02

PROJECTS ● EPE StyloPIC ● Infra-Red Autoswitch ● Simple Audio Circuits – 3 ● Rotary Combination Lock.
FEATURES ● Teach-In 2002 – Part 9 ● Practically Speaking ● Using The PIC's PCLATH Command ● Ingenuity Unlimited ● Circuit Surgery ● New Technology Update ● Net Work–The Internet Page.





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PROJECTS ● *EPE* Bounty Treasure Hunter ● IC Tester ● Headset Communicator ● PIC-Pocket Battleships.
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PROJECTS ● *EPE* Hybrid Computer – 1 ● Tuning Fork and Metronome ● Transient Tracker ● PICAXE Projects–1 (Egg Timer – Dice Machine – Quiz Game Monitor).
FEATURES ● Practically Speaking ● Ingenuity Unlimited ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page.

DEC '02

PROJECTS ● Versatile PIC Flasher ● *EPE* Hybrid Computer – 2 ● Door Defender ● PICAXE Projects – 2 (Temperature Sensor – Voltage Sensor – VU Indicator).
FEATURES ● Electronic Paper ● Alternative Uses for Transistors ● Interface ● Circuit Surgery ● New Technology Update ● Ingenuity Unlimited ● Net Work – The Internet Page ● 2002 Annual Index.





JAN '03

PROJECTS ● *EPE* Minder ● F.M. Frequency Surfer ● Wind Speed Meter ● PICAXE Projects–3 (Chaser Lights).
FEATURES ● Who Really Invented The Transistor ● TechnoTalk ● Circuit Surgery ● Practically Speaking ● New Technology Update ● Computer GOTOs ● Ingenuity Unlimited ● Net Work – The Internet Page.

FEB '03

PROJECTS ● Wind Tunnel ● Brainibot Buggy ● Back To Basics–1 (Hearing Aid, Audio Power Amplifier) ● Tesla High Voltage Transformer.
FEATURES ● In The Bag ● Techno Talk ● Circuit Surgery ● New Technology Update ● Interface ● Ingenuity Unlimited ● Net Work – The Internet Page.

MAR '03

PROJECTS ● Wind-Up Torch Mk II ● 200kHz Function Generator ● Driver Alert ● Back-To-Basics–2 (Metal Detector, Simple Timer).
FEATURES ● Ingenuity Unlimited ● Practically Speaking ● Techno Talk ● New Technology Update ● Circuit Surgery ● Peak LCR Component Analyser Review ● Net Work – The Internet Page.

APR '03

PROJECTS ● Atmospherics Monitor ● Intelligent Garden Lights Controller ● Back-To-Basics–3 (Touch Light, Plant Watering Reminder) ● Earth Resistivity Logger–Part 1.
FEATURES ● Ingenuity Unlimited ● Techno Talk ● New Technology Update ● Circuit Surgery ● Interface ● Network – The Internet Page ● *SPECIAL SUPPLEMENT* – EPE PIC Tutorial V2–Part 1.

MAY '03

PROJECTS ● Super Motion Sensor ● Earth Resistivity Logger – Part 2 ● Door Chime ● Back-To-Basics–4 (Live Wire Detector, Medium Wave Radio).
FEATURES ● Ingenuity Unlimited ● Techno Talk ● Practically Speaking ● Circuit Surgery ● Net Work – The Internet Page ● *SPECIAL SUPPLEMENT* – EPE PIC Tutorial V2 – Part 2.





JUNE '03

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FEATURES ● Ingenuity Unlimited ● Techno Talk ● Interface ● Circuit Surgery ● New Technology Update ● Net Work – The Internet Page ● *SPECIAL SUPPLEMENT* – EPE PIC Tutorial V2 – Part 3.

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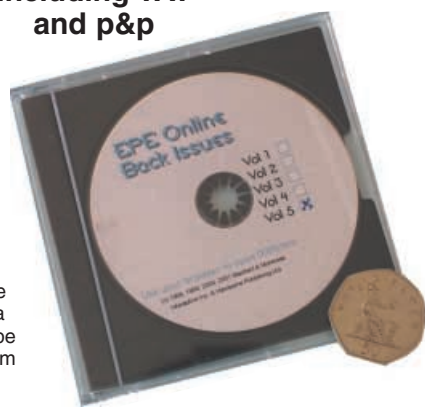
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Email: john.becker@wimborne.co.uk

John Becker addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly.

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★ LETTER OF THE MONTH ★

FLOW CHARTS AND PICS

Dear EPE,

I have recently finished reading Part 3 of your excellent *PIC Tutorial V2* and would just like to offer some comments on the Programming and PICs vs. Hardware sections.

With regard to Programming, flowcharting has not been "in vogue" for quite some time for a number of reasons:

1. It is just as difficult to write as a program, so why not write the program?

2. It was used to document programs, however it was/is difficult to include in "normal" documentation (i.e. text files or in early versions of Word documents) so it tended to be ignored. Diagramming tools are starting to make a comeback with the latest PC capabilities but they tend to have moved on to UML and DFD (Unified Modelling Language and Data Flow Diagram) etc.

3. They were extremely difficult to update to match changes in the program so people maintaining systems tended to distrust them (or use them only to get an idea of the original program concept).

4. Most importantly they simply give a different view of the program, but did not document the context or system view which tends to be more meaningful to give the "why" rather than just the "how" (this is probably why UML and DFD are preferred).

Regarding Hardware, if replacing lots of i.c.s was the sole aim, then we would use FPGAs a lot more. The MCU style of chip does provide functionality and allows complex interactions with data inputs which would be difficult with "normal" chips. However, MCU do have the drawback of relatively slow responses (although, they are reasonably fast and the speed is rarely an issue for hobbyist/semi-professional work). If you want both quick immediate response to inputs, complex responses and minimal chip count then a Programmable System on a Chip (PSoC) may be the answer (I have not played with one yet but they look interesting!).

As a last comment, in production systems chip/device count is very important as it impacts on size, power needs, cost of manufacture etc, and can have a real impact on the profitability of the device. Most of these considerations are not that relevant for hobbyists, but reducing cost and complexity (= chance for mistakes) is always of benefit.

Jon Rigter,
Canberra, Australia

Thank you Jon, you confirm my beliefs! Thanks too for the beneficial information you have been giving me about Visual Basic through our private email chats.

FISH FINDING

Dear EPE,

I take Kyaw Swa Thant's *Readout* question seriously (*Babel Fish?* April '03) – as I do SONAR.

If he wants to build from scratch then he is really serious and several questions need to be answered:

1. Is the fishing going to take place on: (a) a lake, (b) the sea or (c) a river bank?

If (c) then I do not think anyone has sorted this problem, unless the river is as wide as a lake in which case it is an (a) problem! Hunter fish normally use electro-sensing to detect prey and I do not think we humans have developed sufficiently sensitive equipment thus far! If searching takes place at sea or on a lake (i.e. from a boat) then matters get simpler perhaps.

2. What size are the fish? This might dictate the sounding frequency – the smaller the fish the higher the frequency needed to detect it/them. But as a qualification to this, I have just read a WW2 account of *HMS Warrior* where the destroyer encountered a shoal of fish *and* a U Boat. The search frequency was, I gather, 15kHz.

3. What kind of indicator is called for? Is it: (a) directional only, or (b) plan position (usually used by submarines).

I am quite happy to provide info as and where I can help.

David McCloy, via email

Thank you David. If Kyaw cares to contact us at EPE *via email I'll send it on to you.*

PORTABLE PIC PROGRAMMER

Dear EPE,

As a regular *EPE* reader I get to see what the latest ideas are in the electronics field. I saw in the March edition *Readout* a short discussion about a mobile PIC programmer. You also said that if there were enough requests then you would look at this as a project. It would be ideal for the school that I run. We teach hardware and software and also analogue. There is also a small side-line business for the kids who often do small production runs of some of the projects they are requested to look into and develop.

As a source for the data which is used for the programmer why not use a smart card EEPROM? It could be loaded with the hex file via a simple adapter using the serial port. This way if more of these products were ever to be needed, this smart card is simply taken from a manual rolodex containing the cards and loaded into the programmer. I brought this up in class and all responded with a clear *yes*, but no one considered themselves good enough to tackle this project. Are you still thinking about this?

Harry, South Africa, via email

Thanks Harry, I had not considered the type of application you envisage but can see that the idea does have merit. However, if I do ever do one I would not be using a smart card, about which I know nothing, but probably use an EEPROM chip. These devices have been demonstrated in use in several of my PIC projects. Although not so "portable" as a smart card, they have the advantage of being a "known" product to readers.

PIC-O-MANIACS

Dear EPE,

I am an avid reader of *EPE* and have been so since 1978. I look forward each month to receiving the new edition. I have also been involved with PICs for the past seven years. I noticed a revamped version of the *PIC Tutorial* was coming and eagerly awaited my April issue, which takes eight weeks to hit the bookshops here in New Zealand. Imagine my delight when I opened the article to find you had converted the files to the industry standard MPASM. It's such a fantastic piece of work putting the *Tutorial* together and getting people started in this easy way.

I have learned Assembler, then Basic and latterly C programming. However, I often revert from the higher level languages to verify things in Assembler. I firmly believe that a thorough understanding of Assembler is the key to success with more complex firmware designs.

Of all the published magazines you are doing the best job supporting us PIC-O-Maniacs. There is a very good publication out of Australia which is starting to catch up but *EPE* definitely leads the way. One request, how about a few designs using the 12F675 in it's conventional form as opposed to the PIC-AXE version?

Many thanks for years of motivating and rewarding projects and articles.

Mark Weir, Wellington,
New Zealand, via email

Many thanks for your kind comments, Mark – I am well pleased how readers have taken to my PIC Tuts*, both V1 and V2. It's interesting that you revert from high level to low level to check your logic. If I'm developing something complex I sometimes write it first in Basic and then translate to Assembler. Error checking using a PC's screen for readout with Basic is far easier than setting up a PIC to output via an l.c.d., to fully check logic, although this method too has great merits.*

Incidentally, we have an excellent PIC debugging tool coming up, Richard Hinkley's PIC Breakpoint*, which a group of us have been helping Richard to field-test and finalise. It is scheduled for the November issue.*

As you may gather I am PIC-addicted (and thankfully there's no known cure)! One day I'll look into the 12Fx (or a reader might), so keep reading us!

PRACTICALLY SPACED

Dear EPE,

Practically Speaking in July '03, which included notes about spacers, brought to mind my method of doing this.

I use model aircraft fuel tubing of a suitable diameter and cut to an appropriate length. This has a number of advantages:

It is an insulator against the p.c.b. tracks. It is a push fit onto the bolts so that they are held in place while fitting the p.c.b. Because the bolts can move a bit, it doesn't matter if the holes are not exactly lined up. You can't overtighten the nuts as the tubing simply compresses. It is cheap.

Peter Hardy, via email

Thanks Peter, that sounds useful!

ORG-ANIC PICS

Dear EPE,

I have built your *Toolkit TK3* and am trying to run programs from various books, such as Robert Penfold's *Intro to PIC Micro* and D. Smith's *PIC in Practice*. In each case I get an error message "No ORG found" when I try to assemble. I am no expert, this is my first foray into PICs and have tried different permutations without success. Can you help or point me in the right direction, before it all ends up in the bin.

Anthony Coen,
Thetford, Norfolk, via email

Don't bin it Anthony! ORG simply says where the start of the program is to be placed, usually ORG 0 or ORG 5 (although it does have other uses). Try putting ORG 5 immediately prior to the first command. ORG is explained more fully in Part 1 of my PIC Tutorial V2 *in the April issue. I suggest you read and experiment with the whole three-part series.*

CRYSTALISED FRUITS

Dear EPE,

As a radio amateur I'm pleased to see your new series of radio projects from Raymond Haigh. You might be interested to know that my upper 6th Electronics "A" level group all built crystal sets and found that *outstanding* results were obtained by simply connecting the output to a pair of cheap amplified PC speakers. Logical really, as I suspect the input impedance is probably at least 10kΩ, offering better selectivity due to lower damping. Try it and see!

Also, it's been a while since you did any PIC/RC servo projects. How about a "trainable" servo controller to scan a small camera back and forth, up and down, with the ability to have presets, scan between set points etc. 360 degree coverage could be arranged by stacking two servos on top of each other, then having the tilt servo on top of that lot, if you see what I mean.

Gareth Evans,
via email

Thank you Gareth, yes Raymond's series is very welcome, and we are pleased to hear of your interesting results at school. Successfully building radio receivers, crystal or otherwise, has always been a fruitful pursuit, going right back to the days of Marconi even!

We do not have anything on PIC/RC servo in the pipeline, but someone might be encouraged to offer us something useful after reading your letter.

SIMPLER GLCD CODING

Dear EPE,

Thank you for running your *PIC Tutorial V2*, it has lots more useful information and is well worth reading over and over. Under the I²C section I notice you haven't used this format on PICs other than the 16F87x. In the 16F84 to g.l.c.d. routine I sent you and which you put on your ftp site, there is an I²C routine that should run on most PICs, but may need tidying.

Also, a long while back, I read John Becker's *How to Use Graphics L.C.D.s with PICs* (Feb '01) and experimented with another g.l.c.d. device. I also sent John an ASM listing for running a graphics l.c.d. (g.l.c.d.) via shift registers and said I would apply my findings to a normal glcd hook-up. I have found that status checks are not necessary on g.l.c.d.s and simple timing delays work even at a 20MHz PIC clock. This means a large-ish saving in code space and eases the learning curve a bit.

Part of getting to grips with g.l.c.d.s was learning more about "normal" text l.c.d.s. Using a shift register interface, I ended up with a routine that will setup an alphanumeric l.c.d., with timing, S/R, command, character and number subroutines, in 35 PIC commands. This too will run at 20MHz. As it only uses any three I/O pins (two of which could be used as inputs when no l.c.d. work is in progress) you might find it useful in program development when I/O pins are in short supply.

I include here my "timing" routine for g.l.c.d.s based around John's SENDCMD subroutine. I had a little trouble understanding the original SENDCMD and particularly OUTDATA subs, but then I realised that any change to D0-D7, CD, RD and WR had no effect until CE is clocked low. This simplistic view was applied to the following subs in which CE is the key. Finding the timing was simply a matter of counting passes through BTFSC in the CHECK subs in his GEPE456 prog.

The T6963 chip (as in John's g.l.c.d. example) is a lot faster than the HD4470 used in some other l.c.d.s and approximately 8μs delay is used with a built in safety margin and only applied to command data. PICs don't appear to run fast enough to "overload" on autowrite data input. Interestingly, the first call to PAUSIT isn't needed! I didn't even change INTCON settings.

I appreciate John's efforts in getting g.l.c.d.s to work, especially with the limited data available, and understand any reluctance to change tack. It gave me something to tune (I don't make engines, I rebuild, modify and tune them). Here's my code for the 20MHz g.l.c.d. version, which will also work with any slower crystal rate. Change CLKCNT BSF values if time is at a premium. Replace the existing SENDCMD and OUTDATA subroutines with the following. Also rem out all calls for CHECKS 3, 6, 8, and replace all calls to AUTOWRITE with CALL OUTDATA.

```
SENDCMD: movwf PORTD       ; place word
                             on D0-D7
         bsf CLKCNT,5      ; value is
                             nearest Xtal
                             whole num-
                             ber * 1·5
SC:      decfsz CLKCNT,f   ; rough timer
                             to give over
                             8μs
         goto SC
         movlw %00011010
         movwf PORTC       ; set CE, WR
                             low
         goto DWELL        ; wait for port
                             to stabilise
OUTDATA: movwf PORTD       ; place word
                             on D0-D7
         movlw %00010010   ;1 0 0 1 0
         movwf PORTC       ; set CD, CE,
                             WR low
DWELL:   bsf CLKCNT,3      ; use bsf
                             temp,3
                             above
                             15MHz, 2
                             above
                             10MHz,
                           ; 1 above
                             5MHZ & 0
                             under
                             5MHz
TIME:    decfsz CLKCNT,f   ; rough timer
                             to give
                             about 2μs
         goto TIME
         bsf PORTC,2       ; data and
                             control line
                             words
                             "clocked in"
         return
```

Graham Card, via email

Interesting that you've got round the Check situation – well done Graham. I have put your above code into PIC Tricks *on our ftp site, together with the longer example program you sent, and its additional notes.*

Of course, using a timing delay will be familiar to anyone using alphanumeric displays as this is the only technique in use with these devices in EPE *projects. Regarding PAUSIT, have you checked that the g.l.c.d. will initialise immediately power is switched on, even with a power supply that has a slow rise-time for its final regulated voltage?*

I haven't yet had the need for I²C on an F84 but I'll keep your previous code in mind should I do so, thanks for it. Continue enjoying your PICing!

PIC ASM COLUMNS

Dear EPE,

Having built the Magenta version of the *Toolkit TK3* board and tested it out ok I proceeded to your *PIC Tutorial V2* of Apr-Jun '03, but haven't got far! When I tried to assemble the code for Tutorial 2, I was greeted with a multitude of errors. As the code "looked correct" I began to comment out lines to try and trace my fault.

It seems that the assembler does not like the GOTO command. If I just leave in the first GOTO 5 the error produced is "5 command unfound at line 2". Both GOTO 5 statements produce "5 command unfound at line 2", "5 command unfound at line 4", and "GOTO duplicate labels at Prog Counts 0004 & 0000". GOTO is a valid command. I have very limited knowledge on assembly programming and to have been stopped short so early on in the Tutorial has given me some cause for concern. Any help at all would be most gratefully received.

Bryan Keane, via email

I assume Bryan that you mean you are typing in the commands, and I suspect you are not following the layout of the listings in my Tutorial. *Commands like GOTO etc have to be in column 2 (i.e. at least one space character from the left of the screen page before the statement. If you are doing what I think you are, you are putting your GOTO in column 1, but column 1 (starting hard left of line) is where PIC assembly programmers expect to find such things as labels, not commands.*

So to take the first part of program TK3TUT3 as an example, note the separation of columns 1 and 2:

```
STATUS   EQU 3
PORTB    EQU 6
         ORG 0
         GOTO 5
         ORG 4
         GOTO 5
         ORG 5
         CLRF PORTB
         BSF STATUS,5
         CLRF PORTB
         BCF STATUS,5
LOOPIT   BSF PORTB,0
         etc.
```

In fact the assembly program looks for more than just two columns, depending on the nature of the commands. Just a single space or tab key can separate the columns, and where appropriate commas also are taken as separators. Taking LOOPIT BSF PORTB,0 as an example, the assembler splits the line into four columns as follows, taking appropriate action depending on the information in each:

Col 1	*Col 2*	*Col 3*	*Col 4*
LOOPIT	*BSF*	*PORTB*	*0*

So you will see that putting your GOTO 5 at the left of the screen page resulted in the assembler seeing things as:

Col 1	*Col 2*
GOTO	*5*

and so treating GOTO as a label, and 5 as a command, which of course it is not.

AVR PROGRAMMER

Dear EPE,

I have just one wish – if *EPE* can come up with a similar *Toolkit* for both programming and development for Atmel's AVR microcontrollers (e.g. AT90S2313, AT90S8515, etc) as you have for PICs with *TK3*, that will be great !

Davis (aka techy fellow), via email

Well Davis Techy Fellow, we tried readers on Atmel chips some years back but there was a very poor response, so we are sticking with PICs (although we could reconsider AVRs if enough of you twist our arms!).

Special Feature

DIGITAL COMMAND CONTROL FOR MODEL TRAINS



JOHN WALLER

How the computer age has caught up with controlling model trains

EARLY model trains used steam or clockwork as the energy source for their locomotives. Indeed, some of the earliest steam locomotives were tested in model form.

Between 1920 and 1930, electric energy sources with analogue control were introduced. Some early examples used batteries, although trains operating off transformers soon followed.

Until recently, full-size ("real") electric traction motors were nearly all of the series-wound commutator type, which have a very favourable torque-speed characteristic for traction use. These motor types have a field winding and armature in series, and have the useful property that reversal of the current does not affect the direction of rotation.

This property allows the motor to operate off alternating current (a.c.) as well as direct current (d.c.), provided that the a.c. frequency is not too high. This type of motor is still common in mains-powered hand tools, where 50Hz or 60Hz is tolerable for power outputs which are a fraction of a kilowatt.

In "real" a.c. locomotives, 50Hz is too high in frequency for the much larger motor size. Frequencies around 20Hz were introduced, and are still in use in some places.

But, for model trains which use a.c. and series-wound motors, 50Hz to 60Hz is quite satisfactory. Such trains, exemplified by manufacturers Lionel and Märklin, used variable transformers to control train speed. A special relay was fitted to the locomotive to reverse direction, which was activated by sending it a high voltage pulse.

TWO-RAIL RUNNING

Early electrically powered model trains mostly used a three-rail system. Sometimes the third rail was disguised as a series of small posts between the running rails.

This evolved into the two-rail concept, which is now ubiquitous. The two running rails, to which the track voltage is applied, are electrically isolated from each other. All wheel sets in the train must have electrically isolated wheels. Some or all of the locomotive wheels are designed to pick up track current, as well as the wheels on any car which requires current.

Traction motors are separately-excited d.c. motors, with permanent-magnet field. Train reversing simply means reversing the track current. Speed control, before the advent of solid-state electronics, was usually by rheostat. In terms of locomotive operations, a rheostat is a somewhat retrograde step compared with the variable transformer.

ANALOGUE CONTROL

Solid-state technology spawned a spate of d.c. train controllers from series regulators to pulsed methods. Model train buffs still argue over the relative merits of smooth d.c. and pulsed d.c. A common method of using pulses is shown in Fig.1, wherein the d.c. controller generates a series of pulses, which are effectively smoothed by the locomotive motor, although the motor will chatter if the pulse frequency is too low.

Advocates of the pulsed method claim that the high voltage improves slow speed running in the presence of poor contact between wheel and track, although the author has never seen the results of a controlled comparison.

Nearly all electric motor types also act as generators. In the case of the d.c. motor, the generator effect is called *back electromotive force*, or *back-e.m.f.* for short. If the locomotive motor is spun it will generate a voltage proportional to the rotational speed, and this is the back-e.m.f. In practice, the motor adjusts its speed until the impressed voltage, back-e.m.f. and torque out to the load are in balance.

The latter is conditional, of course, upon the motor being able to generate the necessary torque. Also, if the load torque is too low, the motor speed could increase until it destroyed itself. In a model locomotive, the motor usually has too much self-friction for this to occur.

Smart pulsed controllers soon emerged which measured the back-e.m.f. by sensing the track voltage between pulses, as shown in Fig.1. The back-e.m.f. as seen by the controller is "noisy" as it is subject to varying contact resistance between wheel and rail.

A smoothed version of the back-e.m.f. is compared with a control voltage set by the user, with the difference used to control pulse width. The peak pulse voltage of 14V shown is typical for small scale model trains.

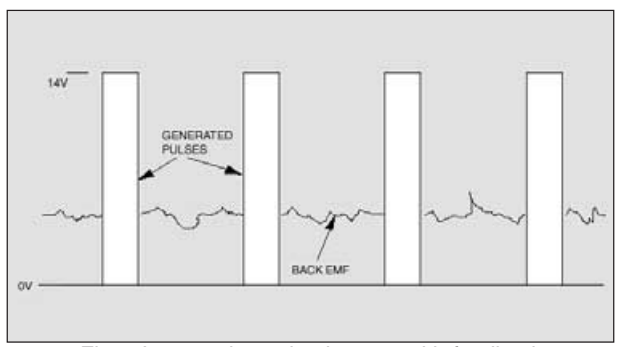


Fig.1. Locomotive pulsed power with feedback.

SIMULATED INERTIA

A real train, if left with its brakes released, will run away (without the help of any traction) on a very small gradient in the track. A model train with locomotive coupled will never run away, as the friction in the motor is too high. Many model locomotives will jerk to a sudden stop if power is removed, although very good locomotives, with a large

fraction of their interior devoted to flywheels, will coast several centimetres.

The obvious remedy is to vary the control voltage to simulate inertia, and this is now commonly done.

FORMS OF MULTIPLEXING

The limitations of the "analogue" train control systems described so far are that a given locomotive needs its own dedicated section of track to operate. To operate several trains, the track layout must be divided into electrically isolated sections, each with its own control switch. In addition, without some auxiliary power system, train lights, for example, extinguish when the train stops; not very realistic.

Various forms of providing multiplexed signals to the locomotive have been developed, using power split up into frequency bands, with each locomotive assigned a specific frequency, or using time slots in a waveform. In any case, the signal also provides power, which then becomes common throughout the layout, obviating the need for isolated track sections.

Power is applied to the track whether trains are moving or not, so lights can be on all the time.

Obviously, any multiplexing system requires the locomotive to be fitted with a decoder. The system which has come to the fore is called Digital Command Control (DCC).

BRIEF HISTORY OF DCC

In 1980 Lenz Elektronik of Germany started marketing a system called Digital Plus. In 1990 the National Model Railroad Association (NMRA) in the USA formed a working group to survey all the multiplexed command control systems on the market. The Digital Plus system stood out as having a high signal-to-noise ratio, and the flexibility necessary for expansion.

The NMRA then defined the standards and recommended practices for DCC, using Digital Plus as a starting point, but moving far beyond it. Lenz has two patents in Germany for the technology, but relinquished the rights outside of Germany. The DCC group is now a separate entity within the NMRA structure, and may be visited at **www.nmra.org**.

The whole philosophy with DCC is to specify the minimum standard which will allow a locomotive decoder from any manufacturer to work with a control system from any other manufacturer. This basically means any signal connected to the track running rails must follow the standard. Signals elsewhere in the system, such as what is done with the output of the decoder in the locomotive, or inputs from the user into the control system, are the individual manufacturer's prerogative.

This approach is taken to encourage innovation. Items which meet the NMRA standard carry their stamp of approval. In all respects DCC is more revolutionary than evolutionary, and offers a degree of realism to the modeller not previously attainable.

Although DCC is primarily aimed at locomotive traction functions, decoders may also be used in ancillary equipment, such as level crossing gates, signals, and points (turnouts in North America).

Table 1. Bit Details of a Typical Data Packet

Preamble	*Address byte*	*Instruction byte*	*Error detection byte*
1111111111 Always all ones	OAAAAAAA Contains the address of the intended recipient of the packet	01DUSSSS The 'D' bit is direction; the 'U' bit is undefined; the 'S' bits are speed	EEEEEEEE Each bit is the exclusive OR of the corresponding bits in the address and instruction bytes

Table 2. Bit Timing and Tolerance

One bit	*Zero bit*
Nominal cycle duration 116μs	Each half nominally ≥ 100μs, but maintained nominally equal to each other
Each half duration between 55μs and 61μs	Each half duration between 95μs and 9900μs, but total duration ≤ 12000μs

DCC PROTOCOL

Digital Command Control is an asynchronous serial protocol. It is unusual among such protocols in that the control signal itself also contains all the power necessary to operate all the receivers (locomotives and ancillary items) connected to the system.

DCC is only applicable to two-rail electrification, but, in principle, is independent of the track gauge or scale of the train. Typical track voltage for HO scale trains is 14V, with a current capacity of 10A or more. The DCC controller sends power to the track continuously.

The power form is described as "alternating d.c.", meaning the voltage on the track is constant, but switches polarity about 1500 times each second. Of course, the system has finite bandwidth, and the transition from one polarity to the other takes a finite time, but this does not adversely impact operations.

The switching protocol contains asynchronous serial data as a series of zeros and ones denoted by the time interval between successive polarity switches. Each locomotive in any train contains a decoder which is set to recognise an address in the serial data, which precedes instructions, such as a change in speed, for that particular locomotive. Details of the data packet format are shown in Fig.2, which shows how zeros and ones are transmitted at different spacings, and Fig.3, which shows a complete packet. Further information is shown in Tables 1 and 2, which are based on the NMRA standards; see **www.nmra.org** and **www.tttrains.com** for complete details.

The decoder also enables ancillary functions so that, for example, the train lights may be turned on or off from the DCC controller. Other ancillary capabilities include simulated steam exhaust noise, firebox flickering light, whistles, diesel engine rumble, and many others. The essential differences between analogue control and DCC are shown in Table 3.

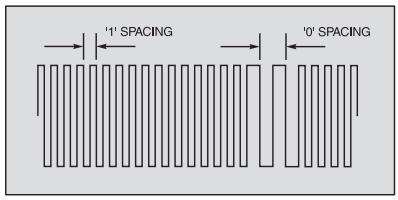


Fig.2. A small snippet of DCC protocol packet.

A consequence of the high current available from DCC track power sources is that short-circuit currents must be interrupted very quickly. Typically, a power source will have fold-back protection so that all trains will stop suddenly in the presence of a short. Unless corrected, a prevalent source of shorts is the "frog" on points, the frog being the place where two running rails of opposite polarity cross.

Special points are now available where the check rail on the frog is insulated to reduce the possibility of shorts. Existing points may be modified by inserting an insulating section in the check rail.

SIGNAL ENCODING

The DCC signal is typically encoded as shown in Fig.3. The aim is to keep the d.c. level of the signal close to zero, to allow the decoder to measure the time between zero crossings, much the same as where digital data are transmitted by radio.

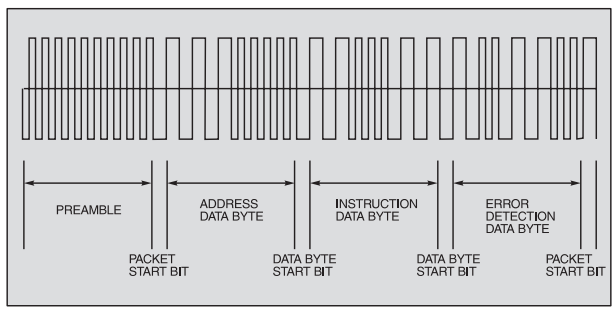


Fig.3. A typical data packet.

Each "packet" is preceded by a preamble, which is just a string of square waves, at "1" spacing, to allow the decoder to synchronise or re-synchronise in the presence of dirty track. Beyond the preamble, each part of the packet is preceded by a start bit at "0" spacing.

The NMRA standards allow for 9999 locomotive addresses. Naturally, they cannot all be used at one time! The DCC controller has means of placing locomotive addresses, and their action orders, on a queue, with other addresses and orders. The contents of the queue are then transmitted in the packet as just described. The length of time taken to send the packet is clearly dependent mostly on the number of

Table 3. Differences Between Analogue Control and Digital Command Control

Analogue	*DCC*
Each train must operate on its own electrically isolated section of track	The whole track is connected to a single source of power, there are no electrically isolated sections, and all trains receive the same power
The train speed is determined by the track voltage within its own section	The track voltage is constant and train speed is determined by the track voltage pattern; each train being controlled has its own address
There are no universal standards	The NMRA sets DCC standards. A DCC controller by a particular manufacturer, which has been approved by the NMRA, must operate correctly with a decoder from any manufacturer, which has been likewise approved
Train ancillaries, such as lights, must have their own power supply if they are not to be dependent on track voltage (the lights go out when the train stops)	Constant lighting, and other ancillary features, specified in the DCC standards, are supplied from the track voltage and can be activated at will by the user
The overall control system characteristics must be a compromise among the various locomotives in use	DCC allows each individual locomotive to have its own control settings; no compromising is necessary

locomotives in the queue, with a limit of 30 being typical.

SIGNAL DECODING

A baseline decoder is shown in Fig.4, which is based on an illustration in the EasyDCC manual from CVP Products. The locomotive wheels pick up current from the running rails to power the decoder.

This is a critical part of electric model train operations, and DCC is no exception. The track running rails must be clean, as well as the locomotive wheels and the brushes which collect current from the wheels.

The decoder is looking for its address in the packet protocol of Fig.3. If found, the subsequent bits are decoded and action taken accordingly. For the simple decoder shown, the actions comprise setting speed and direction, and turning the lights on and off. As already mentioned, other decoder functions are often included, and there are decoders designed for static ancillary functions.

The decoder controls motor speed and direction, using a closed-loop system, but without the complication of wheel to rail contact resistance being present within the loop. Furthermore, the decoder can be programmed to provide inertia. As mentioned earlier, this is available in advanced analogue systems, but there is always a compromise in setting the amount of inertia to suit all the locomotives on the layout.

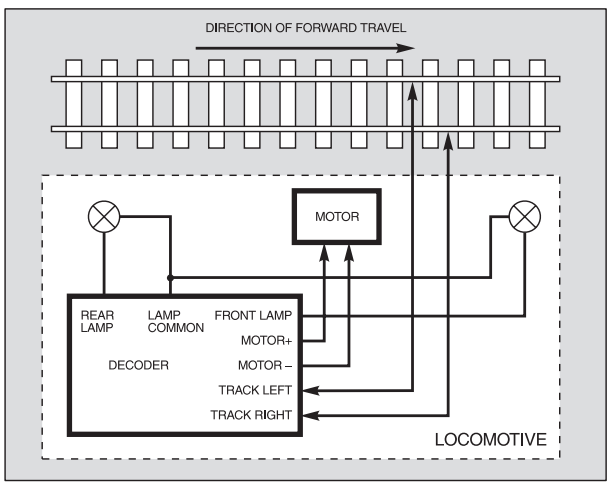


Fig.4. A Baseline locomotive DCC decoder.

Performance differs markedly among individual locomotives. With DCC decoders, each locomotive may be given inertia appropriate to it and it alone. Acceleration and deceleration may be set to different values from each other.

Additionally, friction requires that the locomotive motor receives some minimum current before it will move from a standstill. Again, the DCC decoder allows the user to program each individual locomotive with its own starting current, to obtain a more realistically smooth start.

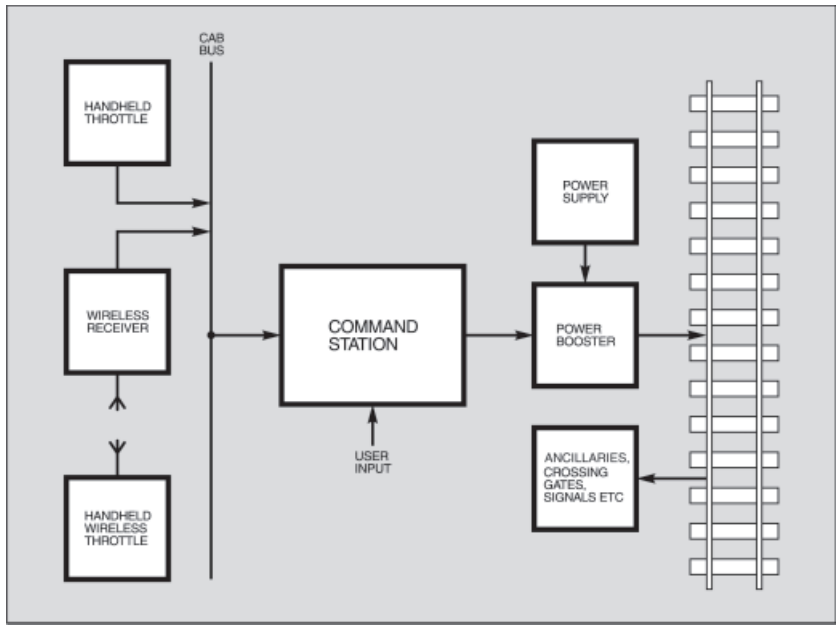


Fig.5. Representative elements of Digital Command Control.

REPRESENTATIVE DCC SYSTEM

The heart of the DCC system, shown in Fig.5, is a Command Station (CS), which generates the serial protocol shown in Fig.3. The output from the CS is boosted to the power level necessary to run all the trains on the system (an HO loco typically requires about 0·5A), together with any ancillaries drawing power from the rails.

The CS has its own user interface, in addition to the "cab bus" shown. A cab, in DCC parlance, refers to the locomotive driver's compartment, or engineer's compartment in North America.

The cab bus allows several users to be controlling trains simultaneously, through hand-held throttles (regulators) connected to the cab bus, either directly or through a wireless link.

The CS provides facilities for controlling trains, setting locomotive and ancillary decoder parameters, and matching these parameter settings with those for the CS. For example, DCC standards provide three speed step values, covering the range from

slowest speed to maximum speed in 14, 28, or 128 steps, respectively.

For a given locomotive, a throttle, whether hand-held or on the CS, must match the speed step setting for that locomotive. Depending on the CS configuration, a locomotive decoder's parameter values are set by placing the locomotive on a special programming track, on the main track, or either. Any attempt to control a locomotive or train from more than one throttle simultaneously produces erratic (and sometimes hilarious) results.

DRAWBACKS OF DCC

Although Table 3 lists the impressive advantages of DCC, the system of Fig.5 suffers from a potential drawback. Particularly in large layouts, where trains can disappear from view, maybe for minutes at a time, users can lose track of which train has which address, and where it is.

In an analogue system, a user, out of sight of other users, will be in charge of a particular section of track, and can prevent collisions by adjusting that section's track voltage. This is not a satisfactory method for DCC, as the principle of track voltage being the same everywhere is violated.

The out-of-sight user must be furnished with a list of trains, and their addresses, identify the train at risk, adjust a throttle to the correct address, and set the train speed for safety. But this will not be successful unless other users do not have that train's address selected on their throttles.

PIC CONTROL

The author has been working to overcome this problem, and has designed and built a PIC-based Smart Throttle, which keeps track of trains and resolves conflicting speed orders. The prototype, whose block diagram is shown in Fig.6, uses a PIC16F877 with RS232 interface to an EasyDCC CS.

Track sensors allow the Smart Throttle to track trains, always matching a train's position to its decoder address, and reducing train speed as required to avoid hazards. The user still has control over trains, but the user-set speed is overridden by the Smart Throttle, where appropriate, in a block and signal control system.

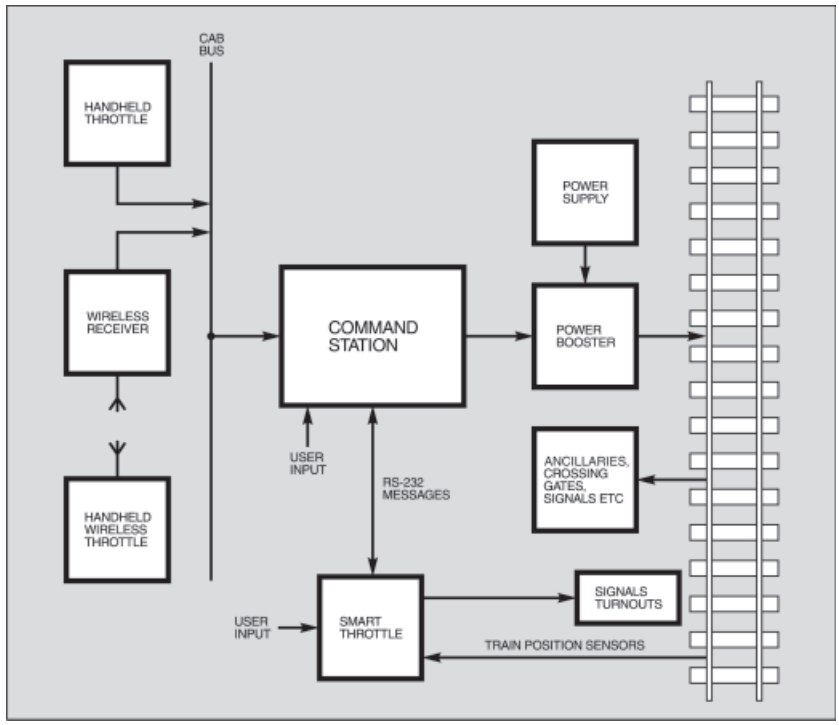


Fig.6. Adding a Smart Throttle to Digital Command Control.

Again, if the Smart Throttle is controlling a given train, all other throttles must deselect that train. But, within the Smart Throttle environment, conflicting speed orders are resolved by rules, such as always selecting the slower (slowest) speed to send to the CS.

The prototype Smart Throttle controls a small layout to demonstrate the effectiveness of sensor inputs, and the various control algorithms. Signal values (colour or semaphore position) are output directly to user-visible signals, but they are for information only.

Potentially, points can also be controlled. Unlike most "real" trains, but universally so in models, the signals do not directly control train speed. In principle, the signal values could be sent from the Smart Throttle to the CS, and thence to ancillaries. The Smart Throttle divides the track layout up into sections or blocks, and no train may enter a block, unless it is declared vacant.

The Smart Throttle prototype is specifically configured for the simple track layout used for development.

For the concept to be viable, it must be adaptable to any layout, and preferably work with a variety of DCC systems. The author continues to work on these aspects.

DCC MANUFACTURERS

A list of some manufacturers of DCC Command Stations is given in Table 4. There are other manufacturers who make decoders and ancillary equipment. There are 12 manufacturers listed, of whom five report currently having an RS232 interface, with one more (ZTC) scheduled for completion in September 2003.

Those manufacturers listed as "not known" in the third column did not answer correspondence on the matter. The author has been using CVP Products for all work so far, but intends to add a ZTC product, as soon as the interface is made available, to give the project an international flavour.

Table 4. DCC manufacturer's web sites

Manufacturer	*Web address*	*RS232 Link*
Arnold Digital, Germany	www.arnold-digital.de	Not known
CVP Products, Texas, USA	www.cvpusa.com	Yes
Digitrax, Inc., Georgia, USA	www.digitrax.com	Yes
Ernst Paul Lehmann Patentwerk LGB, Germany	www.lgb.com	Not known
Lenz Elektronik GmbH, Germany	www.lenz.com	Yes
Model Rectifier Corporation, New Jersey, USA	www.modelrectifier.com	No
North Coast Engineering, New York, USA	www.ncedcc.com	Yes
ROCO Modellspielwaren GES. M. b. H. & Co. KG, Austria	www.infodellbahan.de	Not known
TRIX Modelleisenbahn Gmbh & Co.KG, Germany	www.modellbahanhersteller.de	No
Wangrow Electronics, Inc., Illinois, USA	www.wangrow.com	Yes
ZIMO Elektronik, Austria	www.zimo.at	Not known
ZTC Systems, UK	www.ztccontrols.co.uk	Sept. 2003?

CONCLUSION

The advantages of DCC for the serious railway modeller are considerable. Any hobbyist, whether beginner or otherwise, is well advised to take them into account when starting or modifying a model train layout. Improvements to DCC, including those by the author, will continue to occur.

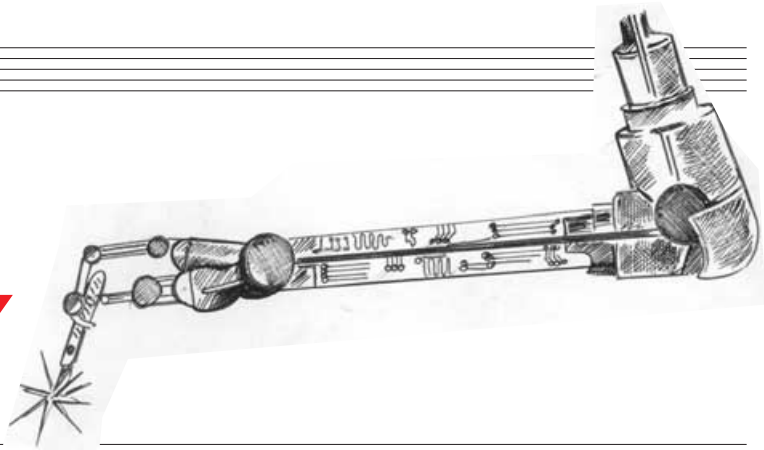
ACKNOWLEDGEMENT

The author is indebted to Brian Barnt, the DCC Manager for the National Model Railroad Association, for the history of DCC model control. □

The author may be contacted at john.waller@snet.net.

Regular Clinic

CIRCUIT SURGERY



ALAN WINSTANLEY and IAN BELL

Our surgeons offer a brief introduction to SPICE during the process of trying to unravel some mysteries of a reader's inverter circuit.

The SPICE Boys

Muhammed Abdallah Saif from Uganda emailed about his inverter circuit.

I am designing an inverter using a 555 timer, with the output at pin 3 fed to a 4013 dual D-type flip-flop. The 4013 outputs (Q and $\overline{Q}$) are connected through a 1kΩ resistor to BC558 transistors with collector resistors of 330kΩ. Their outputs are connected to two 2N3055 power transistors.

The timer has frequency of 200Hz, which should give 50Hz from the 4013. The supply is 12V d.c. The output from one transistor is higher than the other, why? Also, can the 4013 really produce bi-phase outputs?

We'll try to answer the question shortly, though from your written description it is difficult to work out exactly what circuit you are using. This is often the case with the written circuit descriptions that we receive, as in general it is very difficult to describe circuits in prose form.

If you do manage, the description will inevitably be very long and complicated. For this reason it is always better to include a schematic diagram when corresponding with us (or anyone else) about a circuit.

When using email you can scan a drawing or create a drawing on the computer using an image editor and attach it to the email. There are of course packages that are specifically for drawing circuit schematics, but these may have their own formats, which cannot be read by other software.

It is often better to use standard image formats (e.g. jpeg or PDF) that don't require very specialist programs to read them. If you email images, make sure the file sizes are as small as possible whilst being legible. It is bad netiquette to send people large images unless they are expecting them!

If you are restricted to using plain text for any reason (e.g. if posting into an online forum) it is possible to draw "ASCII-matics" using symbols from a non-proportional font such as Courier, but this can be hard work done by hand. A great program that creates ASCII pictures or drawings by converting image files is available at **http://go.to/ascgen**.

Netting a List

An alternative way of describing circuits is to write a *netlist*. This is a defined format for writing a wiring list in text. There are a number of formats in use, but perhaps the best known is that employed by the industry standard analogue simulator known generically as SPICE. We will describe a simplified form of the SPICE netlist as it will be of use to many readers.

Each line of a SPICE netlist has the following format:

ComponentName Connections [model] Parameters

The component name identifies an individual component in the circuit. The first letter of the component name identifies the component type as follows (for basic analogue devices). Obviously this can be extended for other components.

C	Capacitor
D	Diode
I	Independent Current Source
J	Junction Field Effect Transistor (JFET)
K	Mutual Inductor
L	Inductor
M	Metal-Oxide-Semiconductor FET (MOSFET)
Q	Bipolar Junction Transistor (BJT)
T	Transmission Line
V	Independent Voltage Source

A different ***ComponentName*** must be used for each component. The component type determines the number of connections and the order in which they are listed

The ***Connections*** are lists of nodes or "wires" in the circuit. So each interconnection must be given a name, as well as the components. The nodes may be numbered or given meaningful names such as input1 or control. Node zero is always the ground node if numbering is used. The order of the connections is not important for some components such as resistors, but is obviously so for transistors.

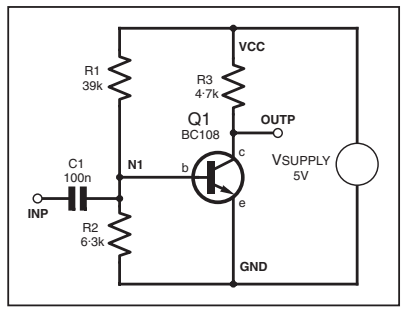


Fig.1. Circuit diagram for a netlist example.

The ***Parameters*** are component values for passive devices and data such as gain for transistors. They may be listed in a predefined order or listed by name.

The ***Model*** is optional and typically used for transistors and diodes. For our purposes it is simply the name of the transistor or diode type used (e.g, 2N3055).

It is best to illustrate the idea of a netlist by example, so here it is for the circuit in Fig. 1. The transistor connections are listed in the order base, emitter, collector. Note that the "wires" are named INP, N1, VCC, OUTP and GND.

```
Q1 n1 gnd outp bc108
C1 inp n1 100n
R1 n1 vcc 39k
R2 gnd n1 6.3k
R3 outp vcc 4.7k
Vsupply vcc gnd 5V
```

Inverted Views

Next month we'll discuss the use of SPICE in more detail. Returning now to the main subject of Muhammed's letter, the basic form of the circuit we assumed is being used, is shown in Fig. 2. This can be described as a "driven push-pull inverter" (self oscillating push-pull inverter circuits are also possible). The drive circuit (in this case the 555 oscillator, 4013, and BC558s) provides two 180 degrees out of phase waveforms to the drive transistors' bases.

The problem of different voltages on the transistors outputs is difficult to evaluate. We do not know the specific circuit, and the reader does not say exactly what was

measured (r.m.s. voltage, peak current, d.c. offset etc.). However, transistors vary quite widely in gain between individual devices and this may account for measured differences. Another possibility (hinted at by the second question) is that the drive may not be fully symmetrical.

The signals at the two drive transistor bases may have different rise and fall times and the two pulse trains may overlap or have a gap in times when both are high. This could happen due to uneven loading on Q and $\overline{Q}$ in the circuit used, or simply be due to the different timing characteristics of these two outputs.

This may not be a major problem at the low frequencies used, but the exact switching characteristics of inverter drive signals can be of critical importance in high speed, high power, or high efficiency inverters and similar power switching circuits. In general, in some circuits specifically overlapping or non-overlapping two-phase clocks are required.

The bi-phase drive waveform can be obtained from a D-type flip-flop (e.g. 4013) wired as a "toggle" flip-flop as shown in Fig. 3. The timing diagram is given in Fig.4. Notice that when the flip-flop is not being reset the output is a square wave at half the clock frequency.

The output square wave will be symmetrical (the signal will be at 0 for the same duration as it is at 1). The Q and $\overline{Q}$ outputs will always be at opposite logic levels, apart from perhaps a short period after the clock edge if the Q and $\overline{Q}$ propagation delays are different.

A further thought – if the 330kΩ resistors described in the reader's circuit are in the current supply path for the 2N3055's bases then it is quite possible that the power transistors are being under-driven. Less than 40μA base current (330kΩ and 12V) in a 2N3055 will result in a few milliamps collector current at the most. This may account for poor performance of the circuit. *I.M.B.*

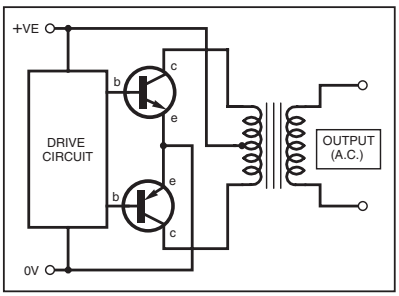


Fig.2 (left). Block schematic diagram for a typical push-pull inverter circuit.

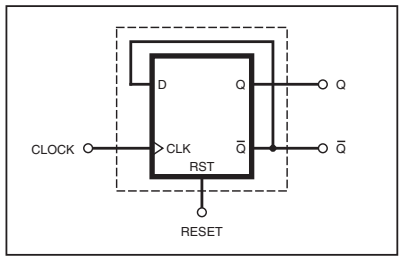


Fig.3. Toggle flip-flop to produce bi-phase drive waveform.

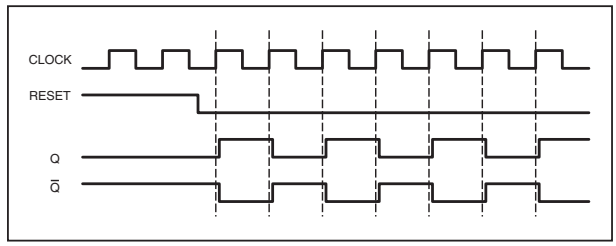


Fig.4. (right). Toggle flip-flop timing diagram.

SHOP TALK with David Barrington

EPE PIC Met Office

As to be expected with a multi-sensor design that makes up the *EPE PIC Met Office* project, some of the component parts are going to be "specials" and not your everyday stock items.

To start with, the Sensym pressure module SCC15AN and Microchip's 24LC256 serial EEPROM memory chip were purchased from **Farnell** (☎ ***0113 263 6311*** or ***www.farnell.com***), codes 179-275 and 300-1696 respectively.

The 40kHz ultrasonic transducers must be the moisture proof, "sealed for external use", types. These were purchased as pairs from **Rapid Electronics** (☎ ***01206 751166*** or ***www.rapidelectronics.co.uk***), codes 35-0182 (Tx) and 35-0184 (Rx). They also supplied the capacitive type humidity sensor, code 61-0960.

Next in line is the rail-to-rail LMC6484 quad op.amp. This was supplied by **RS Components**, code 310-925, and can be ordered through any *bona-fide* stockists, including some of our advertisers. You can order direct (credit card only) from RS on ☎ ***01536 444079*** or ***rswww.com***. Expect to pay a handling charge. They also supplied the optional solar cell panel, code 194-098.

The rest of the semiconductor devices should be straightforward, including the LM35CZ temperature sensor chip. However, it must be the **CZ** type as this version will detect/monitor temperatures down to –40°C and up to +110°C.

For those readers unable to program their own PICs, a ready-programmed PIC16F877-20 (20MHz) microcontroller can be purchased from **Magenta Electronics** (☎ ***01283 565435*** or ***www.magenta2000.co.uk***) for the inclusive price of £10 each (overseas add £1 p&p). They also supplied the 2-line 16-character (per line) alphanumeric l.c.d. module.

The software is available on a 3·5in. PC-compatible disk (PIC Met Office) from the *EPE Editorial Office* for the sum of £3 each (UK), to cover admin costs (for overseas charges see page 579). It is also available for free download from the *EPE* ftp site, which is most easily accessed via the click-link option when you enter the main web site at ***www.epemag.wimborne.co.uk***. On entry to the ftp site take the path ***pub/PICS/PICMetOffice***, downloading all files within the latter folder.

The large printed circuit board is available from the *EPE PCB Service*, code 402 (see page 579).

Finally, due to the vagaries of the environment, it is imperative that constructors treat the finished circuit board with a moisture protection agent. This comes in the form of a plastic/acrylic spray ("conformal coating") in 110ml and 200ml cans. Readers might like to contact: **ESR Components** (☎ ***0191 251 4363*** or ***www.esr.co.uk***) code 251-950; **Rapid** (see above), code 87-1210; and **RS** (see above), code 290-9476.

Practical Radio Circuits – 3

This month's *Practical Radio Circuits* instalment majors on the construction of a single-band *High Performance Regenerative Radio* project. Only a couple of items need highlighting, the rest of the parts should be readily available.

The polythene dielectric tuning capacitor will normally be found listed as a miniature "transistor radio" type and usually consists of an antenna and oscillator section, plus trimmers. The favoured value is 20pF to 126pF range and the two sections should be wired in parallel to give the required 260pF upper range. The miniature tuning capacitor is currently stocked by **ESR Components** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), code 896-110 and **Sherwood Electronics** (see ad. on page 584), code CT9.

The author claims almost any polyvaricon variable capacitor designed for a.m. or a.m./f.m. portable sets should work in the Regen. circuit. The one in the author's model came from **Maplin** (☎ ***0870 264 6000*** or ***www.maplin.co.uk***), code AB11M. Again, you will need to parallel the a.m. sections to give the correct coverage.

The tuning coil is hand-wound from 24s.w.g. (23a.w.g.) enamelled copper wire. A 50g (2oz) reel is stocked by **JAB Electronic Components** (☎ ***0121 682 7045***) or ***www.jabdog.com***). Most suppliers only sell "large" reels.

The two printed circuit boards are available from the *EPE PCB Service*, codes 405 (Regen.) and 406 (T/Cap), see page 579. The optional Wave Trap was covered last month.

Master/Slave Intercom (Top Tenner)

The first of our *Top Tenners* this month is a simple *Master/Slave Intercom* project that can also be used as a "baby alarm".

The article suggests the use of a "plug-top" mains adaptor power supply unit for running the Intercom for prolonged periods of time. It should be capable of delivering up to about 500mA at 6V d.c. and most of our components advertisers should be in a position to offer a suitably rated 3-pin mains plug-top regulated battery eliminator at a reasonable price. You can also use an unregulated type if you wish.

Miniature 8 ohm 40mm (1½in.) to 57mm (2¼in.) diameter loudspeakers seem to be widely stocked and are usually of the paper or Mylar cone types. The LM386 audio power amp i.c. also seems to be a stock item. The author used a 2-pole slider switch for the call/listen function on the Master unit.

The printed circuit board is available from the *EPE PCB Service*, code 407 (Intercom) – see page 579.

Electronic Two-Up (Top Tenner)

The bi-colour l.e.d. used in the *Electronic Two-Up* guessing game, the second of this month's *Top Tenners* projects, is the three-pin version and readers will have some difficulty finding one. We believe the author used an old **Maplin** (☎ ***0870 2263 6000*** or ***www.maplin.co.uk***) device, code CZ45Y (round). We suggest readers use a 3-pin tri-colour 5mm l.e.d. as these are widely stocked and should not cause any problems.

The 4046 phase-locked loop and the 74HC74 dual D-type flip-flop i.c.s should be easy to come by. The printed circuit board is obtainable from the *EPE PCB Service*, code 408 (Two-Up) – see page 579.

Alarm System Fault Finder

All components listed for the *Alarm System Fault Finder* project are standard "off-the-shelf" devices and should not cause any local sourcing problems. The 4001B CMOS quad 2-input NOR gate is certainly found listed in all our component catalogues.

The small printed circuit board is available from the *EPE PCB Service*, code 404 (see page 579).

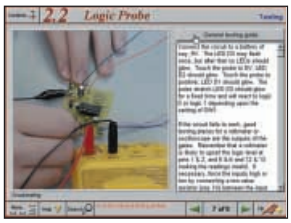
PLEASE TAKE NOTE

Ultimate Egg Timer *(July '03)*

The 74HC4017 counter specified for IC2 in the *Ultimate Egg Timer (Top Tenner)* project has a maximum voltage limit of 6V and could be damaged by the 9V supply shown. To run this circuit at 9V a "standard" CMOS 4017 should be used.

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE
ELECTRONICS CD-ROMS

ELECTRONICS PROJECTS

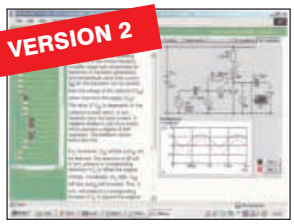


Logic Probe testing

Electronic Projects is split into two main sections: **Building Electronic Projects** contains comprehensive information about the components, tools and techniques used in developing projects from initial concept through to final circuit board production. Extensive use is made of video presentations showing soldering and construction techniques. The second section contains a set of ten projects for students to build, ranging from simple sensor circuits through to power amplifiers. A shareware version of Matrix's CADPACK **schematic capture**, **circuit simulation** and **p.c.b. design** software is included.
The projects on the CD-ROM are: Logic Probe; Light, Heat and Moisture Sensor; NE555 Timer; Egg Timer; Dice Machine; Bike Alarm; Stereo Mixer; Power Amplifier; Sound Activated Switch; Reaction Tester. Full parts lists, schematics and p.c.b. layouts are included on the CD-ROM.

ELECTRONIC CIRCUITS & COMPONENTS V2.0

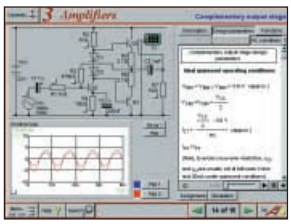
VERSION 2



Circuit simulation screen

Provides an introduction to the principles and application of the most common types of electronic components and shows how they are used to form complete circuits. The virtual laboratories, worked examples and pre-designed circuits allow students to learn, experiment and check their understanding. Version 2 has been considerably expanded in almost every area following a review of major syllabuses (GCSE, GNVQ, A level and HNC). It also contains both European and American circuit symbols. Sections include: ***Fundamentals:*** units & multiples, electricity, electric circuits, alternating circuits. ***Passive Components:*** resistors, capacitors, inductors, transformers. ***Semiconductors:*** diodes, transistors, op.amps, logic gates. ***Passive Circuits. Active Circuits.*** *The Parts Gallery* will help students to recognise common electronic components and their corresponding symbols in circuit diagrams.
Included in the Institutional Versions are multiple choice questions, exam style questions, fault finding virtual laboratories and investigations/worksheets.

ANALOGUE ELECTRONICS

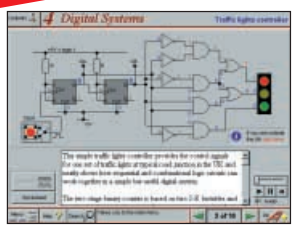


Complimentary output stage

Analogue Electronics is a complete learning resource for this most difficult branch of electronics. The CD-ROM includes a host of virtual laboratories, animations, diagrams, photographs and text as well as a SPICE electronic circuit simulator with over 50 pre-designed circuits.
Sections on the CD-ROM include: **Fundamentals** – Analogue Signals (5 sections),Transistors (4 sections), Waveshaping Circuits (6 sections). **Op.Amps** – 17 sections covering everything from Symbols and Signal Connections to Differentiators. **Amplifiers** – Single Stage Amplifiers (8 sections), Multi-stage Amplifiers (3 sections). **Filters** – Passive Filters (10 sections), Phase Shifting Networks (4 sections), Active Filters (6 sections). **Oscillators** – 6 sections from Positive Feedback to Crystal Oscillators. **Systems** – 12 sections from Audio Pre-Amplifiers to 8-Bit ADC plus a gallery showing representative p.c.b. photos.

DIGITAL ELECTRONICS V2.0

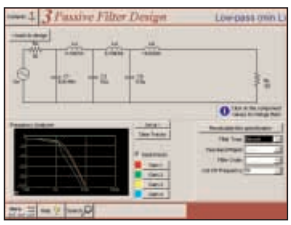
VERSION 2



Virtual laboratory – Traffic Lights

Digital Electronics builds on the knowledge of logic gates covered in *Electronic Circuits & Components* (opposite), and takes users through the subject of digital electronics up to the operation and architecture of microprocessors. The virtual laboratories allow users to operate many circuits on screen.
Covers binary and hexadecimal numbering systems, ASCII, basic logic gates, monostable action and circuits, and bistables – including JK and D-type flip-flops. Multiple gate circuits, equivalent logic functions and specialised logic functions. Introduces sequential logic including clocks and clock circuitry, counters, binary coded decimal and shift registers. A/D and D/A converters, traffic light controllers, memories and microprocessors – architecture, bus systems and their arithmetic logic units. Sections on Boolean Logic and Venn diagrams, displays and chip types have been expanded in Version 2 and new sections include shift registers, digital fault finding, programmable logic controllers, and microcontrollers and microprocessors. The Institutional versions now also include several types of assessment for supervisors, including worksheets, multiple choice tests, fault finding exercises and examination questions.

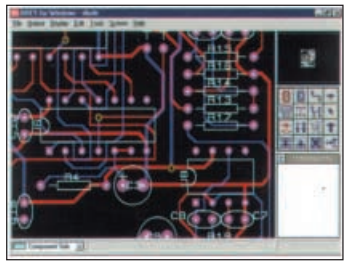
FILTERS



Filter synthesis

Filters is a complete course in designing active and passive filters that makes use of highly interactive virtual laboratories and simulations to explain how filters are designed. It is split into five chapters: **Revision** which provides underpinning knowledge required for those who need to design filters. **Filter Basics** which is a course in terminology and filter characterization, important classes of filter, filter order, filter impedance and impedance matching, and effects of different filter types. **Advanced Theory** which covers the use of filter tables, mathematics behind filter design, and an explanation of the design of active filters. **Passive Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev ladder filters. **Active Filter Design** which includes an expert system and filter synthesis tool for the design of low-pass, high-pass, band-pass, and band-stop Bessel, Butterworth and Chebyshev op.amp filters.

ELECTRONICS CAD PACK



PCB Layout

Electronics CADPACK allows users to design complex circuit schematics, to view circuit animations using a unique SPICE-based simulation tool, and to design printed circuit boards. CADPACK is made up of three separate software modules. (These are restricted versions of the full Labcenter software.) **ISIS Lite** which provides full schematic drawing features including full control of drawing appearance, automatic wire routing, and over 6,000 parts. **PROSPICE Lite** (integrated into ISIS Lite) which uses unique animation to show the operation of any circuit with mouse-operated switches, pots. etc. The animation is compiled using a full mixed mode SPICE simulator. **ARES Lite** PCB layout software allows professional quality PCBs to be designed and includes advanced features such as 16-layer boards, SMT components, and an autorouter operating on user generated Net Lists.

ROBOTICS & MECHATRONICS



Case study of the Milford Instruments Spider

Robotics and Mechatronics is designed to enable hobbyists/students with little previous experience of electronics to design and build electromechanical systems. The CD-ROM deals with all aspects of robotics from the control systems used, the transducers available, motors/actuators and the circuits to drive them. Case study material (including the NASA Mars Rover, the Milford Spider and the Furby) is used to show how practical robotic systems are designed. The result is a highly stimulating resource that will make learning, and building robotics and mechatronic systems easier. The Institutional versions have additional worksheets and multiple choice questions.

- Interactive Virtual Laboratories
- Little previous knowledge required
- Mathematics is kept to a minimum and all calculations are explained
- Clear circuit simulations

PRICES

Prices for each of the CD-ROMs above are:

(Order form on third page)

Hobbyist/Student£45 inc VAT
Institutional (Schools/HE/FE/Industry).....£99 *plus* VAT
Institutional 10 user (Network Licence)£199 *plus* VAT
Site Licence.....£499 *plus* VAT

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

PICmicro TUTORIALS AND PROGRAMMING

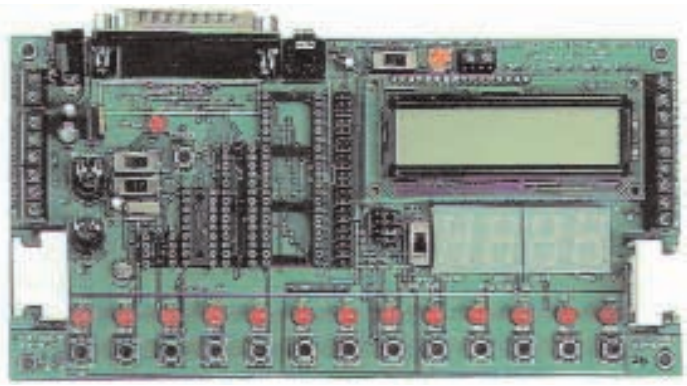
HARDWARE

VERSION 2 PICmicro MCU DEVELOPMENT BOARD

Suitable for use with the three software packages listed below.

This flexible development board allows students to learn both how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40-pin devices. For experienced programmers all programming software is included in the PPP utility that comes with the development board. For those who want to learn, choose one or all of the packages below to use with the Development Board.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 13 individual l.e.d.s, quad 7-segment display and alphanumeric l.c.d. display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- All inputs and outputs available on screw terminal connectors for easy connection



£145 including VAT and postage

12V 500mA plug-top PSU (UK plug) £7

25-way 'D' type connecting cable £5

SOFTWARE

Suitable for use with the Development Board shown above.

ASSEMBLY FOR PICmicro V2

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V2.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes. The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro micro-controller. This is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed which enhances understanding.

● Comprehensive instruction through 39 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.



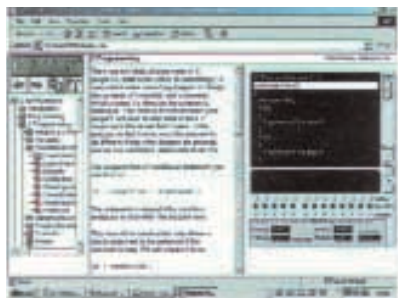
Virtual PICmicro

'C' FOR PICmicro VERSION 2

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running Windows 98, NT, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.

FLOWCODE FOR PICmicro

Flowcode is a very high level language programming system for PICmicro microcontrollers based on flowcharts. Flowcode allows you to design and simulate complex robotics and control systems in a matter of minutes.

Flowcode is a powerful language that uses macros to facilitate the control of complex devices like 7-segment displays, motor controllers and l.c.d. displays. The use of macros allows you to control these electronic devices without getting bogged down in understanding the programming involved.

Flowcode produces MPASM code which is compatible with virtually all PICmicro programmers. When used in conjunction with the Version 2 development board this provides a seamless solution that allows you to program chips in minutes.

● Requires no programming experience ● Allows complex PICmicro applications to be designed quickly ● Uses international standard flow chart symbols (ISO5807) ● Full on-screen simulation allows debugging and speeds up the development process ● Facilitates learning via a full suite of demonstration tutorials ● Produces ASM code for a range of 8, 18, 28 and 40-pin devices ● Institutional versions include virtual systems (burglar alarms, car parks etc.).



Burglar Alarm Simulation

PRICES

Prices for each of the CD-ROMs above are:

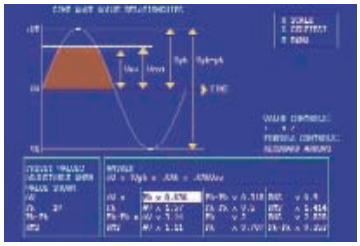
(Order form on next page)

Hobbyist/Student	**£45 inc VAT**
Institutional (Schools/HE/FE/Industry)	**£99 *plus* VAT**
Flowcode Institutional	**£70 *plus* VAT**
Institutional 10 user (Network Licence)	**£249 *plus* VAT**
Site Licence	**£599 *plus* VAT**

(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

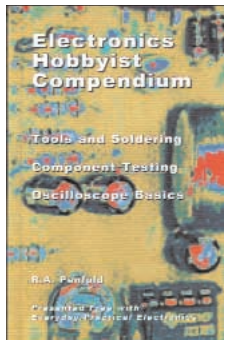
TEACH-IN 2000 – LEARN ELECTRONICS WITH EPE

EPE's own *Teach-In* CD-ROM, contains the full 12-part *Teach-In* series by John Becker in PDF form plus the *Teach-In* interactive software covering all aspects of the series. We have also added Alan Winstanley's highly acclaimed *Basic Soldering Guide* which is fully illustrated and which also includes *Desoldering*. The *Teach-In* series covers: Colour Codes and Resistors, Capacitors, Potentiometers, Sensor Resistors, Ohm's Law, Diodes and L.E.D.s, Waveforms, Frequency and Time, Logic Gates, Binary and Hex Logic, Op.amps, Comparators, Mixers, Audio and Sensor Amplifiers, Transistors, Transformers and Rectifiers, Voltage Regulation, Integration, Differentiation, 7-segment Displays, L.C.D.s, Digital-to-Analogue.



Sine wave relationship values

FREE BOOK WITH TEACH-IN 2000 CD-ROM



Each part has an associated practical section and the series includes a simple PC interface so you can use your PC as a basic oscilloscope with the various circuits.
A hands-on approach to electronics with numerous breadboard circuits to try out.

£12.45 including VAT and postage. Requires Adobe Acrobat (available free from the Internet – **www.adobe.com/acrobat**).

FREE WITH EACH TEACH-IN CD-ROM – *Electronics Hobbyist Compendium* 80-page book by Robert Penfold. Covers Tools For The Job; Component Testing; Oscilloscope Basics.

ELECTRONICS IN CONTROL

Two colourful animated courses for students on one CD-ROM. These cover Key Stage 3 and GCSE syllabuses. **Key Stage 3:** A pictorial look at the Electronics section featuring animations and video clips. Provides an ideal introduction or revision guide, including multi-choice questions with feedback. **GCSE:** Aimed at the Electronics in many Design & Technology courses, it covers many sections of GCSE Electronics. Provides an ideal revision guide with Homework Questions on each chapter. Worked answers with an access code are provided on a special website.

Single User £29 inc. VAT. Multiple User £39 plus VAT
Student copies (available only with a multiple user copy) £6 plus VAT
(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

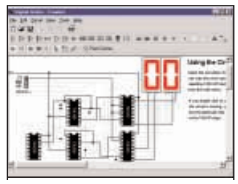
MODULAR CIRCUIT DESIGN

VERSION 3

Contains a range of tried and tested analogue and digital circuit modules, together with the knowledge to use and interface them. Thus allowing anyone with a basic understanding of circuit symbols to design and build their own projects. Version 3 includes data and circuit modules for a range of popular PICs; includes PICAXE circuits, the system which enables a PIC to be programmed without a programmer, and without removing it from the circuit. Shows where to obtain free software downloads to enable BASIC programming.
Essential information for anyone undertaking GCSE or "A" level electronics or technology and for hobbyists who want to get to grips with project design. Over seventy different Input, Processor and Output modules are illustrated and fully described, together with detailed information on construction, fault finding and components, including circuit symbols, pinouts, power supplies, decoupling etc.

Single User £19.95 inc. VAT. Multiple User £34 *plus* VAT
(UK and EU customers add VAT at 17.5% to "plus VAT" prices)

DIGITAL WORKS 3.0



Counter project

Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability ● Software for simulating digital logic circuits ● Create your own macros – highly scalable ● Create your own circuits, components, and i.c.s ● Easy-to-use digital interface ● Animation brings circuits to life ● Vast library of logic macros and 74 series i.c.s with data sheets ● Powerful tool for designing and learning.
Hobbyist/Student £45 inc. VAT.
Institutional £99 *plus* VAT.
Institutional 10 user £199 *plus* VAT.
Site Licence £499 *plus* VAT.

ELECTRONIC COMPONENTS PHOTOS



A high quality selection of over 200 JPG images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).
Also contains a **FREE** 30-day evaluation of Paint Shop Pro 6 – Paint Shop Pro image editing tips and on-line help included!

Price £19.95 inc. VAT

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 95/98/NT/2000/ME/XP, mouse, sound card, web browser.

CD-ROM ORDER FORM

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- ☐ Electronic Circuits & Components V2.0
- ☐ Analogue Electronics
- ☐ Digital Electronics V2.0
- ☐ Filters
- ☐ Electronics CAD Pack
- ☐ Robotics & Mechatronics
- ☐ Assembler for PICmicro
- ☐ 'C' for PICmicro
- ☐ Flowcode for PICmicro
- ☐ Digital Works 3.0

Version required:

- ☐ Hobbyist/Student
- ☐ Institutional
- ☐ Institutional 10 user
- ☐ Site licence

- ☐ PICmicro Development Board (hardware)
- ☐ Development Board UK plugtop power supply
- ☐ Development Board 25-way connecting lead

- ☐ Teach-In 2000 + FREE BOOK
- ☐ Electronic Components Photos
- ☐ Electronics In Control – Single User
- ☐ Electronics In Control – Multiple User
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New Technology Update

Super-cool diamonds may be a major milestone in the development of superconducting technology, reports Ian Poole.

SUPERCONDUCTORS have been known about for many years. They were first discovered in 1911. Despite the "hype" in the news they have not been adopted into as many areas as might have been expected. One of their major drawbacks is the fact that superconductors usually have to be operated at very low temperatures.

Some of the first superconducting materials that were discovered needed to be within a degree or so of absolute zero to exhibit the effect. Above this temperature the effect totally disappeared. Even some of the more recently discovered materials still require to be operated at very low temperatures and this requires that highly sophisticated cooling plants have to be used.

Despite this, the technology is still used in some areas of technology where very high levels of performance are required. One example of this is within the Maglev high speed train in Japan. This magnetically levitated train achieved a speed of 552km/hr in April 1999.

The technology also has applications in the electronics arena as well. Here it finds uses in microwave components where its use enables designers to considerably reduce the level of surface resistance in conductors.

Although superconduction can give significant improvements in performance over standard technologies, the costs of the refrigeration units have often meant that they are not viable for many applications. However, a recent development may mean that the vacuum above a diamond may be able to superconduct at room temperature.

This development at the University of Pretoria is as yet not fully proved, but if it is shown to work then it will certainly be a major milestone on the development roadmap of superconducting technology. It could even lead to the development of room temperature superconductors.

In Theory

The new discovery can be explained by certain aspects that are common with superconducting technology. To understand how superconductors work it is first necessary to investigate how a normal conductor operates.

A conducting material consists of a lattice of nuclei from which electrons are able to break free. These free electrons normally move in a totally random fashion. If a potential is applied across the material then they will drift in a particular direction as a result of the fact that the electrons are attracted by an opposite charge.

However, the electron movement is hindered by the nuclei in the lattice of the material and the impurities in the conductor. This causes the electrons to scatter and not flow in an orderly fashion. This impedes the flow of the electrons and gives rise to resistance.

In the case of a superconductor there is an interaction between the nuclei and electrons but in this case the effect results in electrons being able to flow unimpeded through the lattice. What happens is that as one electron flows through the lattice it distorts the lattice. When a second electron approaches the first, it is attracted by the greater density of the positive charge where the nuclei have been pulled together.

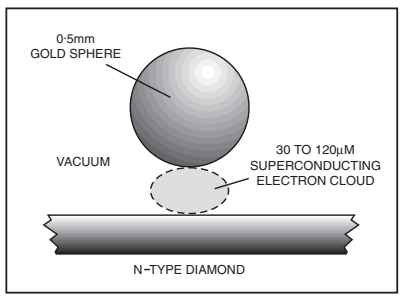


Fig.1. Details of the layout used for the diamond superconduction experiment.

This effect overcomes the repulsive force that would normally exist between two electrons and they travel together as a pair known as a Cooper pair. These pass through the lattice with no obstruction and as a result there is no resistance. It is found that these pairs of electrons each have an opposite spin, and this enables them to be attracted together despite the fact that they have the same charge and would normally repel one another.

As the temperature increases the nuclei start to vibrate more and eventually a point is reached where the Cooper pairs start to break up and the material rapidly reverts to its normal state, along with the associated resistance. This effect can also occur if the level of current becomes too high. This is known as the critical current.

New Discovery

The discoverer of the potentially new phenomenon is Professor Johann Prins at the University of Pretoria. He said that he was researching properties associated with an *n*-type doped diamond surface. In the experiments that he was undertaking he placed a 0·5mm gold sphere within a few micrometers of the surface whilst it was held in a vacuum.

Under these conditions it should have been possible for a current to flow, only under the presence of a large voltage that would cause a breakdown in the gap between the diamond and the gold sphere. As predicted a current flowed when a voltage of 500 volts was applied, but it was also found that current flowed when a very much lower voltage was applied.

One explanation for the current flow under low voltage conditions was that it was caused by some contamination. This was extensively investigated and no trace of contamination was found.

The explanation that is being proposed is that the electrons must exist in pairs. The only way that this can happen without them repelling one another is for them to be in the same macro quantum state as they are in superconductors. Here each electron in the pair has an opposite spin. It also appears that this can only occur in *n*-type doped diamond.

From the observations that have been made so far, the best explanation appears to be that the electrons appear as a cloud of electron pairs in a wave function with zero velocity in the gap between the diamond surface and the small gold sphere – see Fig.1. Electrons that enter the gap from one side do not drift across but become part of the wave, and correspondingly electrons emanate from the other side.

Possibilities

This research is at its very earliest stages. As a result, the theory is developing and new ideas and explanations are being proposed.

It has been mentioned by one party that a related discovery some years ago turned out to be the result only of the impurities that had been introduced into the diamond. Nevertheless, this could still be a very exciting development because it demonstrates the possibility of superconduction at room temperature.

Whilst diamond may be an expensive base to use it is quite possible that the same phenomenon may be able to be replicated on another cheaper base, thereby giving the possibility of true superconducting technology at everyday temperatures for the first time. This would undoubtedly be a major breakthrough and one that could change the whole face of electrical and electronics technology as we know it today.

More information about the latest in radio and electronics technology can be found at **www.radio-electronics.com**.

Constructional Project

PRACTICAL RADIO CIRCUITS



RAYMOND HAIGH

Part 3: Regenerative Receivers – A modern-day version of Armstrong's 1913 circuit.

Dispelling the mysteries of Radio. Circuits for the set builder and experimenter.

In Part Two we reviewed the history and theory of regeneration and used the technique to improve the performance of two, portable, radio receivers. This month a regenerative receiver designed for serious listening on the long, medium and short wave bands will be described.

BASICS

For a regenerative receiver to perform well, three basic requirements have to be met. (1) Its regeneration control must be smooth, completely free from backlash, and have a minimal effect on tuning.

(2) The tuned circuit to which the *Q* enhancing positive feedback is applied must be isolated from the aerial: failure to do this will result in reaction dead spots on frequencies (or harmonics) at which the aerial is resonant.

(3) Provision must be made, at the receiver input, for the attenuation of powerful signals, otherwise the regenerative circuit will lock onto strong carriers and it will not be possible to receive weak transmissions on adjacent channels.

ARMSTRONG UPDATED

A modern, transistor version of Armstrong's circuit, patented in 1913, is shown in Fig.3.1. In the original, the feedback coil (tickler coil in the USA), L3, was connected in place of the radio frequency choke, L4, and regeneration controlled by adjusting its proximity to tuning coil L2. This was eventually superceded by the variable capacitor system shown here, where increasing the capacitance of VC1 increases feedback through L3.

Choke L4, in the drain (d) circuit of TR1, acts as a load for the radio frequency component of the amplified signal, controlled amounts of which are fed back through L3 to overcome losses in the tuned circuit (L2/VC2) and increase its efficiency or *Q* factor.

Armstrong discovered that the technique permits the amplification of weak signals by a factor of more than 1000. Further, because tuned circuit *Q* is raised, there is also a dramatic improvement in selectivity.

Source bias is developed across resistor R3, which is bypassed by capacitor C2, and signal detection occurs by way of rectification at the gate/source junction of transistor TR1. (In the original valve versions, diode rectification between grid and cathode resulted in detection or demodulation). Low value blocking capacitor C1 prevents the audio voltage developed across gate resistor, R1, being shorted by the tuning coil.

AUDIO SIGNAL

The amplified audio signal is developed across drain load resistor R2 and coupled to the audio amplifier stages via d.c. blocking capacitor C3. Residual radio frequencies are bypassed by capacitor C4.

In some versions of the circuit, a transistor type audio transformer (e.g., an LT44) is substituted for the resistive load in order to maximize signal transfer. However, even with this arrangement, the audio output is very low, and at least one additional stage of pre-amplification will be required ahead

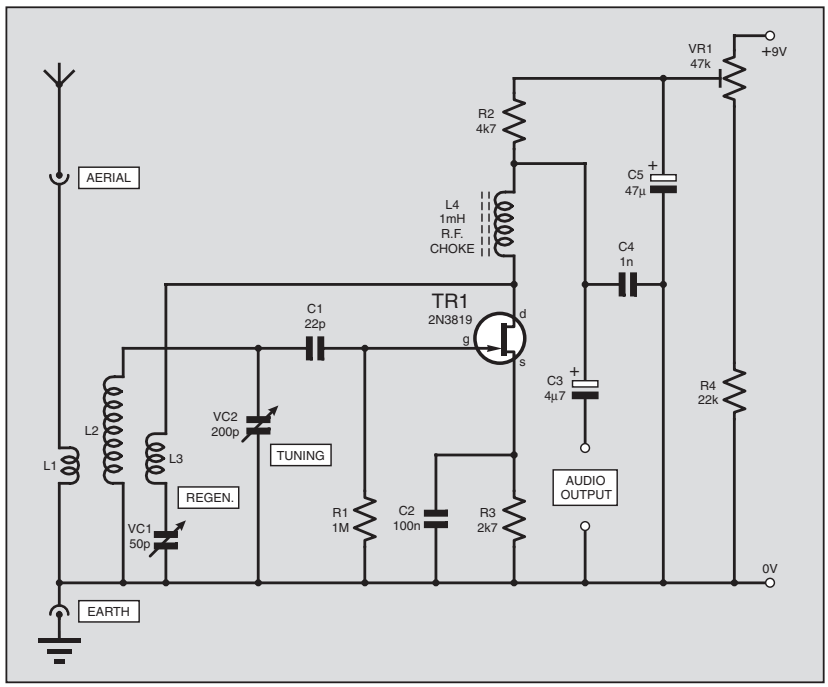


Fig.3.1. Circuit diagram for a modern transistor version of Armstrong's Regenerative Detector. In Armstrong's circuit, patented in 1913, feedback coil L3 is connected in place of r.f. choke L4 and its proximity to L2 is adjusted to control regeneration. VR1 presets regeneration control range.

of the headphone or speaker amplifiers described in Parts 1 and 2.

The gain of TR1, and hence its willingness to regenerate, is determined by preset potentiometer VR1, which adjusts the drain voltage. By this means the circuit can be optimized for different transistors and coil feedback winding ratios.

POPULARITY

Using gradually improving versions of Lee de Forest's triode valve as the amplifying device, Armstrong's circuit, followed by a one or two valve audio amplifier, remained popular as a domestic receiver until the end of the 1920s in the USA and well into the 1930s in the UK. Regenerative receivers were still being manufactured by Ever-Ready (their Model H) as late as the 1950s, and they were constructed by amateurs up to the close of the valve era.

It is not easy to use low impedance, current amplifying bi-polar transistors in this circuit. However, it saw something of a revival in amateur circles following the introduction of the field effect transistor (f.e.t.), with its more valve-like characteristics, in the late 1960s.

IMPROVED CIRCUITS

Smooth regeneration can be obtained more readily, and with simpler coils, by configuring the *Q* multiplier, or regenerative detector, as a Hartley oscillator. A typical circuit is given in Fig.3.2, where feedback from the source(s) of the dual-gate MOSFET, TR1, is connected to a tapping on the tuning coil L2.

The level of feedback is controlled by VR1, which varies the gain of the transistor by adjusting the voltage on its gate g2. Preset potentiometer VR2 (wired as a variable resistor) determines the source bias and optimizes the action of the regeneration control for individual tuning coils and transistors.

Audio output is developed across drain load resistor R3. The stage is decoupled from the supply rail by resistor R2 and capacitor C5, and the filter network formed by C4, R4 and C6 removes radio frequencies from the output.

SEPARATION

During the valve era, the functions of signal detection and *Q* multiplication or regeneration were invariably carried out by a single device. This combining of functions can make it more difficult to obtain the smooth, backlash-free control of regeneration which is crucial to the efficient operation of a receiver of this kind. Best modern practice uses separate transistors.

The dual-gate MOSFET circuit illustrated in Fig.3.2 can be used just as a *Q*-multiplier by increasing the value of capacitor C4 to 100nF. Filter components, R4, C6 and coupling capacitor C7, can be omitted when the stage is configured in this way.

The "hot" end of the tuned circuit must, of course, be connected to gate g1 of the transistor, and resistor R1 is best retained to hold gate g1 at 0V during coil changing.

DETECTORS

A field effect transistor (f.e.t.), biased into the non-linear region of its characteristic curve, forms an excellent detector stage. The "drain bend" version (the transistor equivalent of the valve "anode bend" detector) is included as TR3 in the Regenerative Receiver design illustrated in Fig.3.4. This arrangement is discussed later.

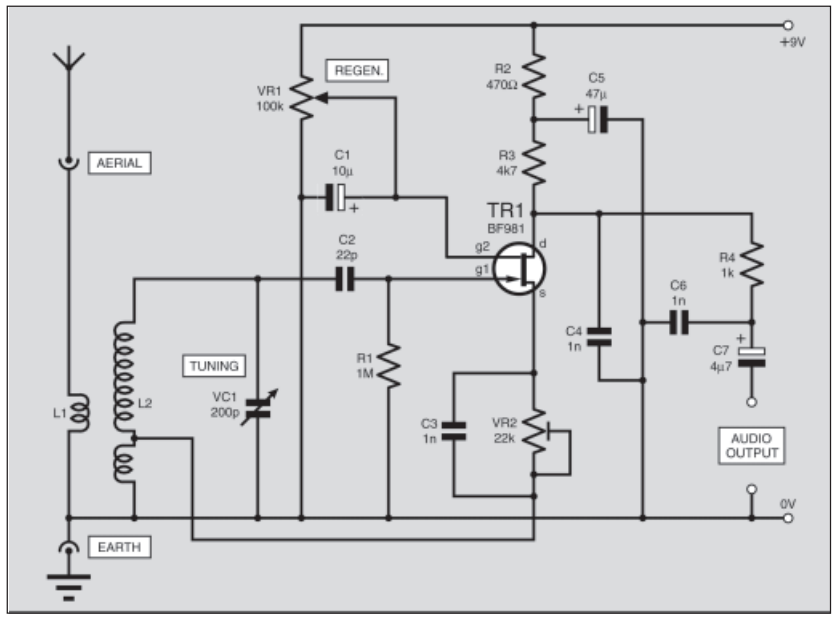


Fig.3.2. Circuit diagram for an improved Regenerative Detector based on a Hartley oscillator. VR2 presets regeneration control range. This circuit forms an excellent Q-Multiplier for use with a separate detector, in which case increase capacitor C4 value to 100nF and delete C6, C7 and R4.

Alternatively, the audio output can be taken from the source of the f.e.t. We then have the transistor equivalent of the valve "infinite impedance" detector. The modified circuit, using the component numbering of Fig.3.4 for ease of comparison, is shown in Fig.3.3.

High-value source bias resistor R9 is bypassed only at radio frequencies by capacitor C10 (C9 is omitted), and C13 is increased to 47μF to decouple the stage which is now in the common drain mode. The r.f. filter components, R8 and C15, and the original decouplers, R6 and C11, are not required.

There is little to choose between the two detectors: both work well, imposing very little damping on the tuned circuit. In theory there is some gain with the drain bend version whilst the gain of the source follower is slightly less than unity.

In practice, the need to ensure non-linearity over a range of f.e.t. characteristics results in the drain bend circuit providing very little gain. If the value of r.f. bypass capacitor C10 in Fig.3.3 is reduced, the source-follower detector may become unstable when the regeneration control is critically set.

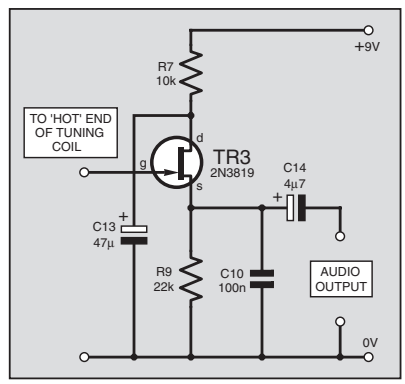
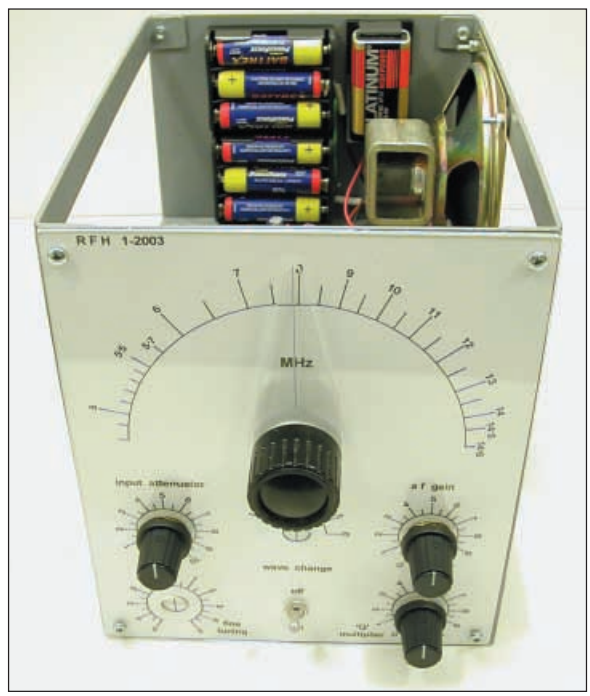
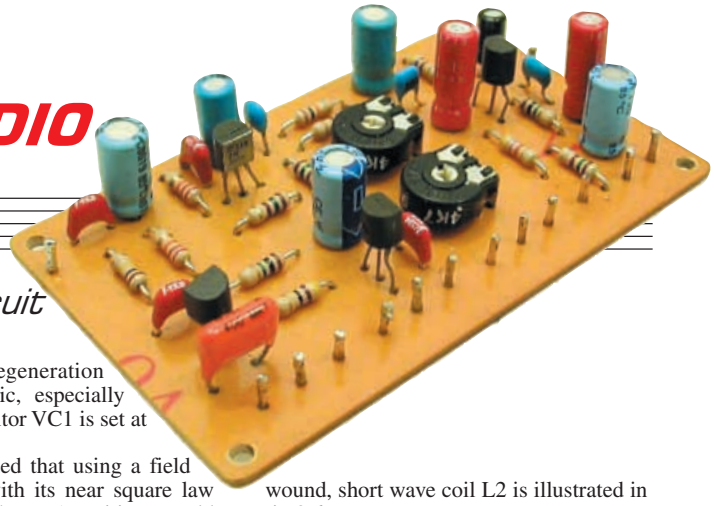


Fig.3.3. Source-follower detector circuit. Transistor equivalent of the valve "anode-bend" detector.



HIGH PERFORMANCE

REGENERATIVE RADIO



A modern-day update of a 1913 circuit

The full circuit diagram for a High Performance Regenerative Radio incorporating the essential features described here is given in Fig.3.4. It is easy to set up and performs well.

Grounded base stage, TR1, isolates the tuned circuit L2/VC1 from the aerial and TR2 functions as the *Q*-Multiplier. Field effect transistor TR3 is a drain bend detector and transistor TR4 an audio preamplifier.

Although excellent *Q* multipliers can be designed around dual-gate MOSFETS (metal-oxide semiconductor field effect transistors), devices of this kind are becoming more difficult to obtain. For this reason a j.f.e.t. (junction field effect transistor) is used in the *Q* multiplier stage.

Performance is not compromised and these simpler devices are widely available. The circuit in Fig.3.2 should assist any readers who might wish to experiment with dual-gate MOSFETS as an alterative.

INPUT CIRCUIT

Some readers may be plagued by a medium wave transmission which is powerful enough to swamp the receiver, and L1 and C1 act as a Wave Trap, blocking out the offending signal. Wave trap circuits were discussed in Part 2 last month, and component values and a printed circuit board design were also given.

Potentiometer VR1 connected as the emitter resistor for transistor TR1, controls signal input, and resistors R2 and R3 fix the base bias. The base of TR1 is "grounded" at radio frequencies by capacitor C5; and R1, C3 and C4 decouple the stage from the supply. Blocking capacitor, C2, prevents the grounding of TR1 emitter when aerials are connected to the receiver via a balun transformer and coaxial cable.

The grounded base configuration results in a low input impedance and a high output impedance, and the stage can be coupled directly to the tuned circuit without imposing excessive damping. Because TR1 is a *pnp* transistor, its collector (c) can be connected to the 0V rail via coil L2, eliminating the need for a coupling winding.

STABILITY MATTERS

Stability is ensured by stopper resistor R4 and by maintaining a low level of base bias on TR1. Constructors may wish to try reducing the value of resistor R3 (not less than 47 kilohms) to improve performance when low gain transistors are used in the aerial input circuit.

However, if this is overdone the stage will no longer be unconditionally stable, and control of regeneration will become erratic, especially when tuning capacitor VC1 is set at a low value.

It could be argued that using a field effect transistor, with its near square law characteristics, in the TR1 position, would reduce the receiver's susceptibility to cross-modulation.

Cross-modulation occurs when a powerful signal drives the input stage into non-linearity. It then begins to function as a modulator, imposing the strong signal on adjacent weaker signals and spreading it across the dial.

The regenerative circuit of Fig.3.4 will lock onto a powerful signal long before it is strong enough to make TR1 non-linear. The measures taken to avoid this (wave trap and input attenuator) will, therefore, also prevent cross-modulation. Moreover, *p*-channel field effect transistors are not so widely available, and this militates against their use.

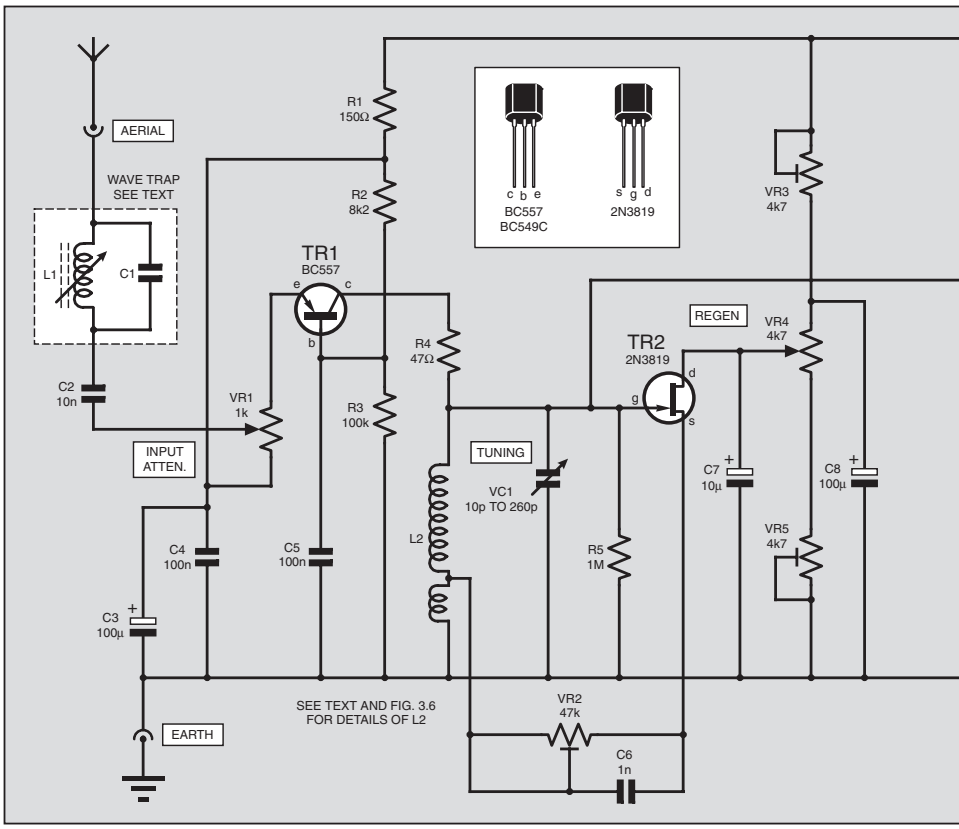
TUNING

The simplest possible tuning arrangement is depicted in Fig.3.4. and the hand-wound, short wave coil L2 is illustrated in Fig.3.6.

The tuning capacitor VC1 is a 10pF to 260pF unit formed by connecting both a.m. gangs of a polyvaricon (polythene dielectric) capacitor in parallel. Typical connection details are shown in Fig.3.7, and the copper track side of a printed circuit board suitable for mounting most screw or tag fixed variable capacitors of this kind is also shown.

REGENERATION

Regeneration, or *Q* multiplication, is provided by TR2, a field effect transistor configured as a Hartley oscillator. Feedback is taken from TR2 source (s) to a tapping on coil L2 via preset potentiometer VR2 and its bypass capacitor C6. This arrangement enables the control of regeneration to be optimized for different coil and transistor combinations.



COMPONENTS

Approx. Cost Guidance Only

£21 *excl. case & batt. & wire*

REGENERATIVE RADIO

See SHOP TALK page

Resistors

R1, R6, R11	150Ω (3 off)
R2	8k2
R3	100k
R4	47Ω
R5, R10	1M (2 off)
R7	10k
R8, R13	470Ω (2 off)
R9	22k
R12	4k7

All 0·25W 5% carbon film

Potentiometers

VR1	1k rotary carbon, lin.
VR2	47k carbon preset, horizontal
VR3, VR5	4k7 carbon preset, horizontal (2 off)
VR4	4k7 rotary carbon, lin.
VR6	4k7 rotary carbon, log.

Capacitors

C1	only required if Wave Trap fitted (see Part 1)
C2	10n disc ceramic
C3, C8, C11, C12	100μ radial elect. 25V (4 off)
C4, C5, C10	100n disc ceramic (3 off)
C6	1n polyester
C7, C9	10μ radial elect. (2 off)
C13, C15	1n polyester or ceramic – see text and Table 3.1 (2 off)
C14, C17	4μ7 radial elect. – see text and Table 3.1 (2 off)
C16	47μ radial elect. – see text and Table 3.1
C18	10n polyester or ceramic – see text and Table 3.1
VC1	10p to 260p polythene dielectric variable capacitor

Semiconductors

TR1	BC557 *pnp* small signal transistor
TR2, TR3	2N3819 *n*-channel field effect transistor (2 off)
TR4	BC549C *npn* silicon transistor

Miscellaneous

L1	only required if Wave Trap fitted (see Part 1)
L2	tuning coil, hand-wound (see Fig.3.6)
S1	d.p.s.t. toggle switch

Printed circuit boards available from the *EPE PCB Service*, codes 405 (Regen) and 406 (T/Cap); diecast or aluminium box for chassis, at least 200mm x 150mm x 75mm (8in. x 6in. × 3in.), or aluminium sheet to fabricate a base and front panel; aerial and earth screw terminals; one large and three small plastic control knobs; audio type screened leads; 50g (2oz) reel of 24s.w.g. (23a.w.g.) enamelled copper wire for tuning coil; plastic tube, 20mm (3/4in.) outside diameter (o/d) for coil former; 9V battery (PP3) and clip; connecting wire; nuts, bolts and washers; solder pins; solder etc.

Feedback is adjusted by regeneration control VR4, which varies the voltage on the drain (d) of TR2 thereby altering its gain. The range of adjustment is fixed by presets VR3 and VR5, and the action of the regeneration control can be made very gentle and smooth when the swing of VC1 is not too great. Potentiometer noise is eliminated by capacitor C7.

DETECTOR PREAMPLIFIER

Drain bend detector, TR3, is biased into non-linearity by resistor R9, which is bypassed at audio and radio frequencies by capacitors C9 and C10. Audio output is developed across drain load resistor R7, and R6 and C11 decouple the stage from the supply rail. Residual radio frequencies are filtered out by R8, C13 and C15, and the signal is coupled to transistor TR4 through d.c. blocking capacitor C14.

Audio preamplifier stage, TR4, is necessary in order to boost the weakest signals. Emitter bias is provided by resistor R13, which is bypassed by C16; R10 is the base bias resistor, and R12 is TR4's collector load.

Supply rail decoupling is effected by R11 and C12. The output signal is taken from TR4 collector, via blocking capacitor C17, and the audio output level is set by Volume control VR6.

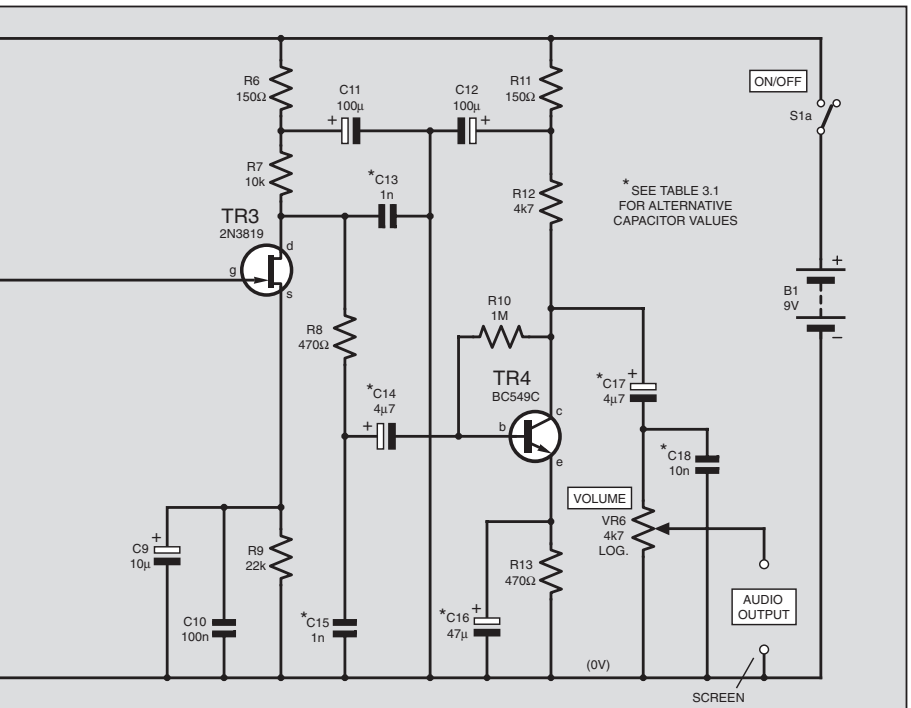


Fig.3.4. Complete circuit diagram for the High Performance Regenerative Radio. See Table 3.1 for alternative capacitor values. Note the Wave Trap is optional – see text and Part 2 (July '03).

Table 3.1. Capacitor Values for a Wide or Narrow Audio Frequency Response

Part No.	*Wide Response*	*Narrow Response*
C13	1n	10n
C14	4μ7	100n
C15	1n	10n
C16	47μ	4μ7
C17	4μ7	100n
C18	10n	330n

AUDIO RESPONSE

Speech signals, especially when they are overlaid by noise, can be greatly clarified by reducing the response of the system to low and high audio frequencies. Telephone companies throughout the world operate on this principle, and heavily attenuate frequencies below 300Hz and above 3000Hz (3kHz). Narrowing the response leaves speech intelligible while removing parts of the spectrum that carry a good deal of the noise.

The values of the capacitors in the receiver's audio signal path, i.e. from the collector of TR3 onwards, can be chosen to tailor the

audio response. Increasing the value of shunt capacitors C13, C15 and C18, will reduce response to high frequencies.

Reducing the value of coupling capacitors, C14 and C17, will attenuate low frequencies. Reducing the value of bypass capacitor C16 introduces selective negative feedback which also inhibits response at the lower audio frequencies.

Suggested alternative values for these capacitors are given in Table 3.1. Readers will no doubt wish to experiment until the audio response meets their needs.

POWER SUPPLY

Even small power amplifiers induce large voltage variations in the supply rail, and the four transistors in this circuit must have their own battery supply (or a supply isolated by an electronic regulator and ample smoothing).

Voltage fluctuations on a common supply will cause erratic regeneration, problems with electronic tuning systems (described next month) and low frequency oscillation or "motor boating". The receiver battery is switched by S1a. The other half of the toggle switch, S1b, can be used to control the supply to the Speaker Amplifier (described last month) or other audio amplifiers.

SEMICONDUCTORS

The *pnp*, bipolar transistor used as the r.f. amplifier, TR1, is not particularly critical. Any small signal device with an f_T of at least 100MHz and an H_{fe} of 200 or more should perform well. The audio preamplifier, TR4, can be almost any small signal *npn* silicon transistor, but low-noise, high gain (H_{fe} at least 400) devices are to be preferred.

Most *n*-channel field effect transistors should function in the detector (TR2) and *Q* multiplier (TR3) stages. In addition to the specified 2N3819's, the BF244A, BF245B, J304, J310, TIS14, K168D and MPF102 have all been "in circuit" tested and found to be satisfactory.

Note that base connections for all of these devices vary and should be checked.

CONSTRUCTION

Most of the receiver components are assembled on a compact printed circuit board (p.c.b.). The topside component layout, together with the full-size underside foil master pattern and off-board wiring are illustrated in Fig.3.5. This board is available from the EPE PCB Service, code 405 (Regen).

The tuning coil L2 and variable capacitor VC1 are mounted separately. This gives greater freedom in the choice of tuning arrangements. A small p.c.b. which will take most miniature screw or tag fixing poythene dielectric variable capacitors is shown in Fig.3.7. This board is also obtainable from the *EPE PCB Service*, code 406 (T/Cap).

Solder pins inserted at the lead-out points ease the task of off-board wiring. They should be inserted into the printed circuit board first. Follow these with the resistors, then the capacitors, smallest first; and, finally, the semiconductors. It is good practice to use a miniature crocodile clip as a heat shunt whilst soldering the field effect transistors in place.

On completion, the p.c.b. should be examined for poor soldered joints and bridged tracks, and the orientation of semiconductors and electrolytic capacitors should also be checked.

It is a good idea to wire the printed circuit board to the controls and tuning components on the work bench, and test it before mounting it in an enclosure. Current consumption of the receiver should be in the region of 4mA.

COIL WINDING

Details of the tuning coil L2 are given in Fig.3.6. It is wound on an off-cut of 20mm (3/4in.) outside diameter plastic electrical conduit and preset VR2 and its bypass capacitor C6 are located at one end of the former. Solder tags are used to anchor the windings and the preset potentiometer.

Plastic electrical conduit for the hand-wound coil is retailed at most DIY outlets. Suppliers of enamelled copper wire and tuning capacitors are mentioned in the *Shoptalk* column. The remaining components are widely available.

The specified variable capacitor (VC1) will tune coil L2 from 4·8MHz to 14·6MHz. This covers the 20, 30 and 40 metre amateur bands, and the 25, 31, 41, and 49 metre broadcast bands.

Details of hand-wound coils covering 150kHz to 30MHz will be described next month, together with switched coil packs, incorporating commercial coils, for general coverage and amateur bands receivers.

Constructors who like to experiment with their own coils should tap longwave inductors at 5 per cent of the total turns, and all other coils at 10 per cent. The shortwave coil covering up to 30MHz may require a 15 per cent tapping point to secure regeneration when the tuning capacitor is set at maximum. Commercial coils in spares boxes can be pressed into service by adding turns to form the source tapping point.

ASSEMBLY AND WIRING

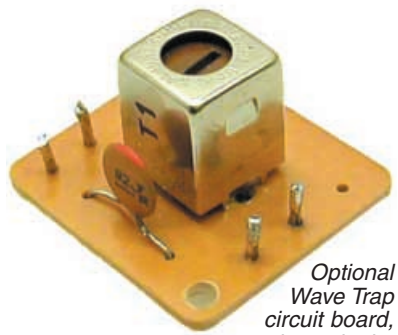
Construction of the set must be rigid and robust or the receiver will not perform well, especially on the shortwave bands. Diecast boxes are best for chassis or enclosures, but receivers assembled on or in aluminium boxes are acceptable. A metal front panel is essential for screening purposes.

Layout is not particularly critical, but locate the tuning components close to the relevant solder pins on the receiver printed circuit board. Keep signal input leads away from output leads. The regeneration potentiometer VR4 can be located in any convenient position (it is decoupled from the signal circuits).

The general interwiring from the p.c.b. to the off-board components is shown in Fig.3.5. Some variable capacitors are secured by screws driven into their front plates. Check the length of the screws to ensure that they do not project too far and foul the capacitor vanes.

Metal potentiometer cases should be connected to the 0V rail. Leads between the aerial terminal, the input attenuator, VR1, and the receiver printed circuit board, should be screened, as should the leads between the volume control, VR6, the power amplifier and the receiver board. The screening must, of course, be connected to the "ground" or 0V rail.

Most polyvaricon capacitors designed for a.m. or a.m./f.m. portable receivers will be suitable. The calibrated dial reproduced (half-size) in Fig.3.8 should be reasonably accurate if the tuning capacitor mentioned in the Components List is used and the coil is wound in accordance with Fig.3.6.



Optional Wave Trap circuit board, not shown in the author's model below.



General layout inside the metal case. The speaker amplifier module is in the foreground. The wave trap is mounted on the underside boxed chassis.

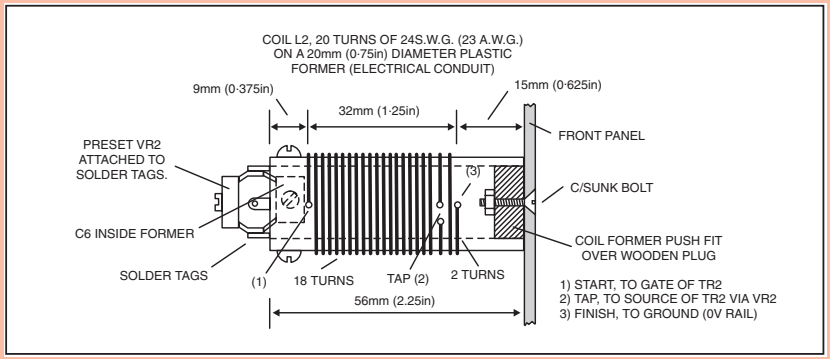




Fig.3.6. Coil winding details for the tuning coil L2. The coil former also carries preset VR2 and capacitor C6 – see photo opposite.

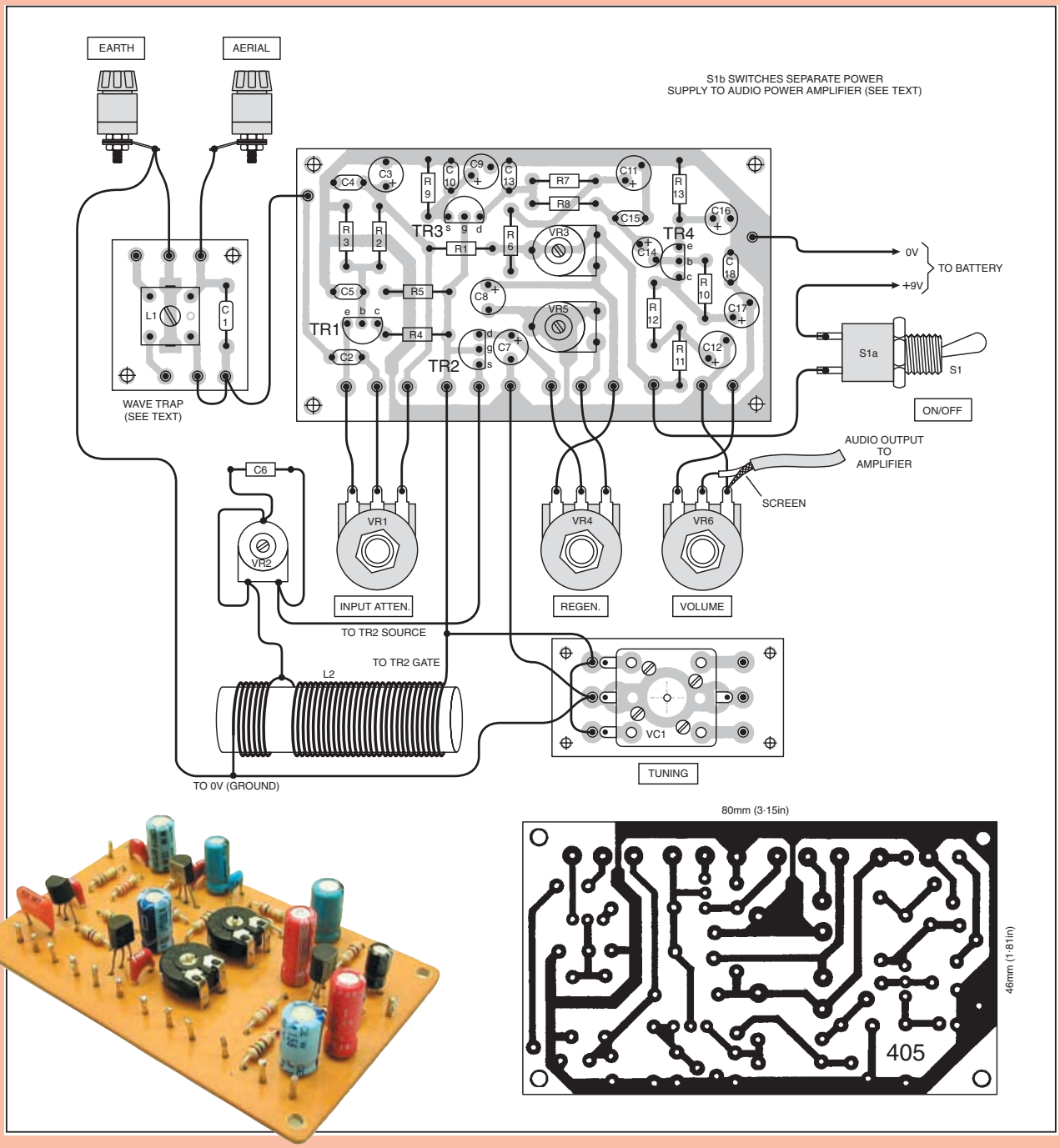
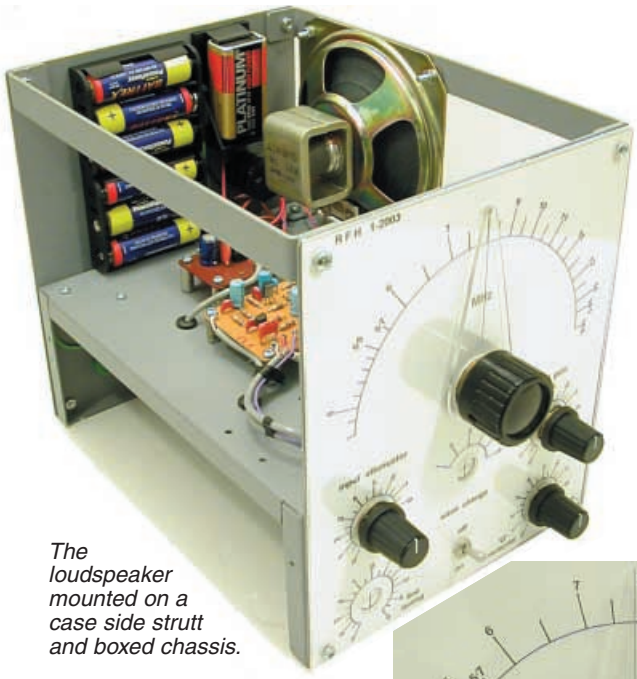


Fig.3.5. Printed circuit board component layout, interwiring details and full-size copper foil master for the Regenerative Receiver. Note you will need an additional VR2 preset and capacitor C6 for each waveband coil.



The loudspeaker mounted on a case side strutt and boxed chassis.

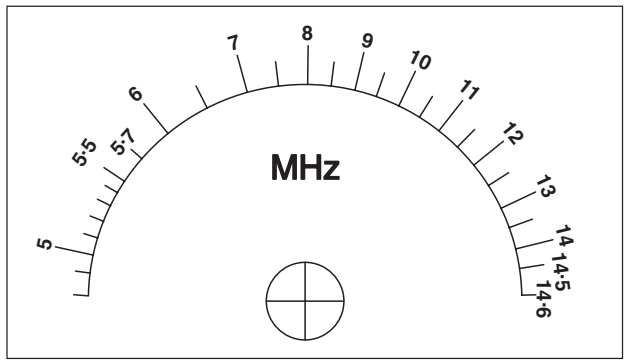


Fig.3.8. Half-size calibrated dial (MHz). Calibration with the specified tuning capacitor and coil L2. Receivers will vary, but it is a good guide to coverage.

Polyvaricons intended for inexpensive 'hi-fi' systems often have 300pF or larger a.m. gangs. These capacitors have a deeper case, around 20mm (3/4in.) compared to the 10mm (3/8in.) or so for the lower value units. Only one gang should be connected if a capacitor of this kind is fitted.

The accompanying photographs show this simple version of the receiver assembled on the metal chassis used to test and evaluate the circuits. A 6:1 reduction drive is fitted to the spindle of the tuning capacitor but this is not adequate for easy tuning over the shortwave bands.

Further, the value of the tuning capacitor, whilst it gives good coverage with the single coil, is too high and regeneration becomes difficult to adjust at the high frequency end of the range. These questions are addressed next month when more refined tuning systems are discussed.



Front panel fascia of single band version showing general layout .

Readers may wish to try connecting only one of the capacitor gangs into circuit. This gives a swing of 5pF to 130pF and coverage with the specified coil is around 6·5MHz to 15·5MHz. Coverage is reduced but control of regeneration, at the higher frequencies, is easier.

SETTING UP

Connect the receiver to the Speaker Amplifier described in Part 2. Connect an aerial comprising at least 30 feet (10 metres) of wire located as high as possible and well clear of any telephone or power lines and earthed objects.

Set preset VR2 to maximum, and presets VR3 and VR5 to minimum resistance. Rotate the slider of Regen. control VR4 to put the maximum voltage on the drain (d) of TR2. Set the other potentiometers to half-travel.

Now connect a fresh 9V battery and tune in a weak signal with variable capacitor VC1, set close to its maximum value.

Reduce the resistance of preset VR2 until the *Q* multiplier begins to oscillate (indicated by a rushing sound or faint whistle). Turn down Regeneration control VR4. The receiver should slide gently out of oscillation.

When regeneration is set close to oscillation, the perceived strength of signals will be greatly increased and tuning much sharper.

Turning down VR1 to attenuate input signals, as necessary, gradually open the vanes of VC1 to tune the receiver up in frequency. Less regeneration will be required to maintain sensitivity as the tuning capacitance is reduced, and VR4 will have to be progressively turned down. When VC1 is fully open, increase the value of preset VR5 until regeneration can be set just below the threshold of oscillation when VR4 is at minimum.

Refine the adjustment of preset potentiometers VR2, VR3 and VR5 until the action of the regeneration control VR4 is as gentle as possible across the entire tuning range. Because of the wide swing of the tuning capacitor, VC1, in this simple version of the receiver, presets VR3 and

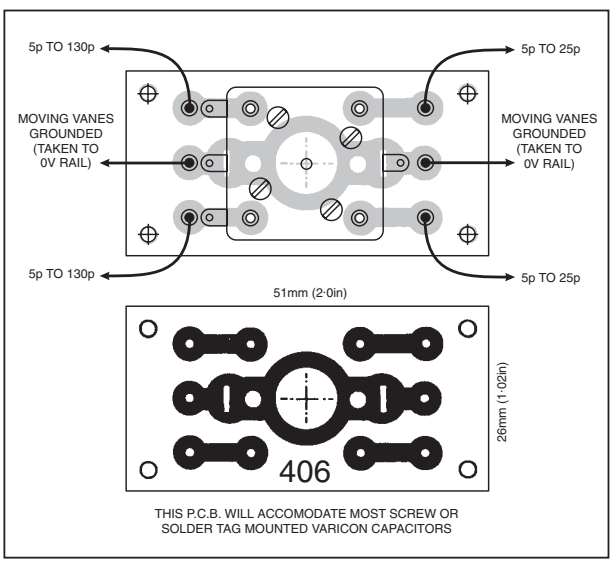
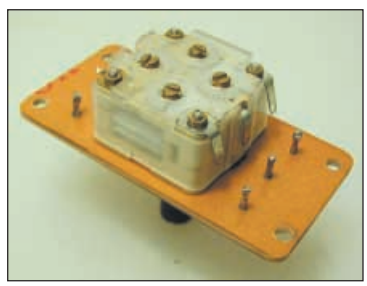
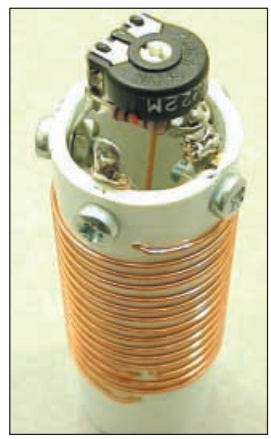


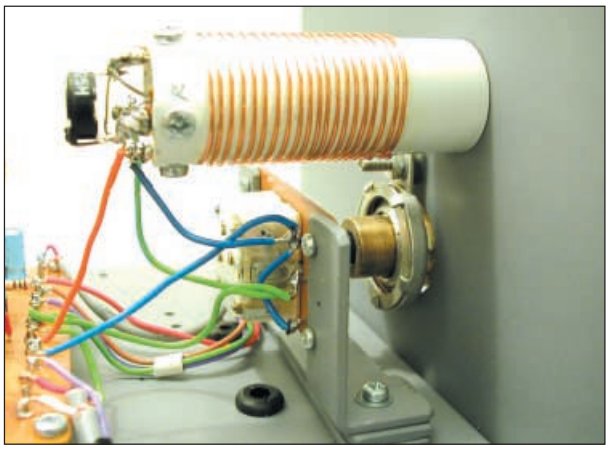
Fig.3.7. Tuning capacitor mounting p.c.b. details. Connections to a typical a.m./f.m. four-gang polythene dielectric variable capacitor. Capacitance values and connections may vary and should be checked.



(Above) The tuning capacitor mounted on the p.c.b.



(Right) Completed tuning coil showing preset soldered to tags bolted on one end of former.



Close-up view of the mounting arrangement for the tuning coil and variable capacitor. Note the reduction drive fitted to the tuning capacitor spindle.

VR5 will have to be set close to minimum resistance to give VR4 sufficient control.

OPERATION

Best results will be obtained if the Regenerative Radio is operated with VR1 set to attenuate the input as much as possible and the audio frequency gain (Volume) control turned up to ensure adequate sound output. This is good practice with complex sets and essential with this simple receiver. If this procedure is not followed it will be impossible to hear weak signals close in frequency to powerful ones.

For best reception of a.m. (amplitude modulated) signals the Regeneration control VR4 must be adjusted, as the receiver is tuned across the band, to keep the *Q* multiplier circuit close to oscillation. When regeneration is correctly set, rocking the tuning control should produce a faint whistle on either side of the station.

A useful technique when searching for very weak signals is to advance the regeneration control until the stage is just oscillating in the absence of a carrier signal. When a station is tuned in its carrier will suppress the oscillation and the weak signal will become audible.

PUBLIC WARNING

This practice was widely adopted when regenerative receivers were popular for domestic listening. Unfortunately there was usually no radio frequency stage to isolate the detector from the aerial, and an oscillating valve with up to 100V on its anode forms a good transmitter.

Reception was, therefore, marred by whistles and howls propagated by neighbouring receivers. The problem became so acute that, in 1928, the BBC issued a handbook guiding the public on the correct operation of the regeneration control. During that year so many complaints were received that listeners were warned that their licenses would be withdrawn if they didn't exercise more restraint.

With this modern transistor design, the grounded base radio frequency stage isolates the very low powered oscillator and interference problems do not arise.

AMATEUR BAND RECEPTION

For the reception of amateur s.s.b. (single-side-band) transmissions, the regeneration control must be advanced until the *Q* multiplier is oscillating. The locally generated oscillation replaces the carrier suppressed at the transmitter so that the signals can be demodulated in the usual way (more about this later).

Very precise tuning is required to clarify these signals, and the simple slow motion drive fitted on this version of the receiver is completely inadequate. Fortunately, the operation of the regeneration control produces a very slight shift in the *Q* multiplier's frequency of oscillation, and this can be used to fine tune and clarify these transmissions (increasing the drain voltage produces a very slight reduction in the gate to source capacitance).

The signals will still be difficult to resolve, however, and next month a tuning system dedicated to the three most popular amateur bands will be described.

An "earth" connection may improve reception. Guidance on constructing an earth system was given in Part 1.

PERFORMANCE

The Regenerative Radio described here is a modern evocation of the 1913 circuit that made man's dream of long distance radio reception a reality. However, it should not be regarded as a historical novelty. Correctly built, connected to a decent aerial and skillfully operated, it will permit the reception of at least 90 per cent of the signals receivable on a modern, high performance communications receiver.

Skilful operation is the key to unlocking its performance. The need for this is, perhaps, the main reason why it was replaced by the more easily controlled superhet receiver.

It lacks automatic gain control, automatic input attenuators and pushbutton tuning. It does, however, offer a standard of performance out of all proportion to the minimal outlay of money and effort involved in its construction.

Next month's article, dealing with more refined tuning systems and general coverage and amateur bands coil packs, will help readers to get the best out of the receiver.

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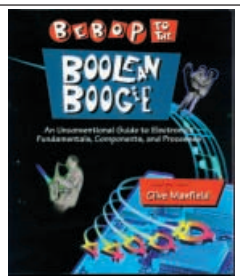
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None of the designs requires the use of any test equipment in order to get them set up properly. Where any setting up is required, the procedures are very straightforward, and they are described in detail.

Projects covered: Simple MIDI tester, Message grabber, Byte grabber, THRU box, MIDI auto switcher, Auto/manual switcher, Manual switcher, MIDI patchbay, MIDI controlled switcher, MIDI lead tester, Program change pedal, Improved program change pedal, Basic mixer, Stereo mixer, Electronic swell pedal, Metronome, Analogue echo unit. ~~£10.95~~

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THE INVENTOR OF STEREO – THE LIFE AND WORKS OF ALAN DOWER BLUMLEIN

Robert Charles Alexander

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Alan Dower Blumlein led an extraordinary life in which his inventive output rate easily surpassed that of Edison, but whose early death during the darkest days of World War Two led to a shroud of secrecy which has covered his life and achievements ever since.

His 1931 Patent for a Binaural Recording System was so revolutionary that most of his contemporaries regarded it as more than 20 years ahead of its time. Even years after his death, the full magnitude of its detail had not been fully utilized. Among his 128 patents are the principal electronic circuits critical to the development of the world's first elecronic television system. During his short working life, Blumlein produced patent after patent breaking entirely new ground in electronic and audio engineering.

During the Second World War, Alan Blumlein was deeply engaged in the very secret work of radar development and contributed enormously to the system eventually to become 'H2S' – blind-bombing radar. Tragically, during an experimental H2S flight in June 1942, the Halifax bomber in which Blumlein and several colleagues were flying, crashed and all aboard were killed. He was just days short of his thirty-ninth birthday.

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VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR

R. A. Penfold

Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.

There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.

Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.

Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply. ~~£10.95~~

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It covers soundcards, sequencers, hard disk digital audio recording and editing, plug-ins, printing scores with notation software, using your PC as a synthesiser, getting music onto and off the Internet, using Windows, sample PC music set-ups, FAQs, a glossary, advice on hardware and software, and a list of industry contacts.

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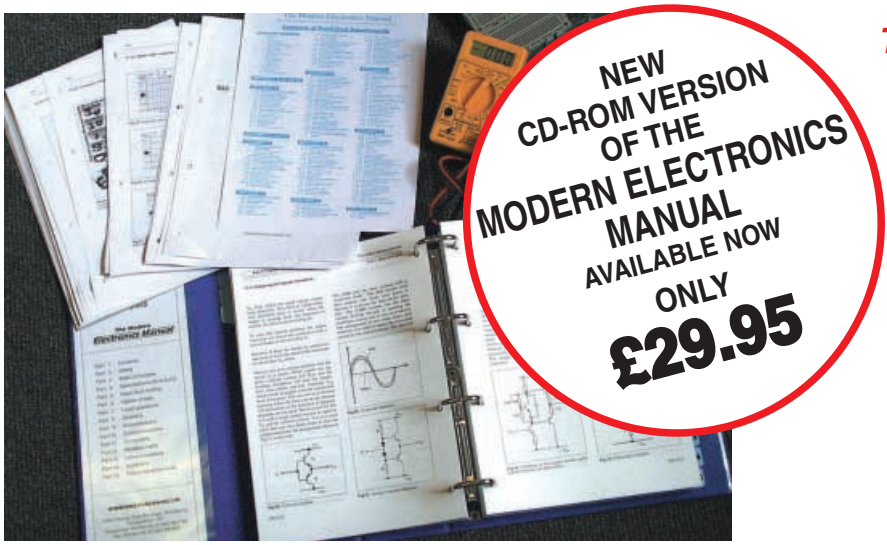
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